2013

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Journal of Sport & Exercise Psychology, 2013, 35, 60-71

JOURNAL OF
SPORT & EXERCISE
PSYCHOLOGY
Official Journal of NASPSPA
www.JSEP-Journal.com
ORIGINAL RESEARCH

Layered Stimulus Response Training Improves Motor Imagery Ability and Movement Execution

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This study aimed to test Lang's bioinformational theory by comparing the effects of layered stimulus and response training (LSRT) with imagery practice on improvements in imagery ability and performance of a motor skill (golf putting) in 24 novices (age, M = 20.13 years; SD = 1.65; 12 female) low in imagery ability. Participants were randomly assigned to a LSRT (introducing stimulus and response propositions to an image in a layered approach), motor imagery (MI) practice, or visual imagery (VI) practice group. Following baseline measures of MI ability and golf putting performance, the LSRT and MI practice groups imaged successfully performing the golf putting task 5 times each day for 4 days whereas the VI practice group imaged the ball rolling into the hole. Only the LSRT group experienced an improvement in kinesthetic MI ability, MI ability of more complex skills, and actual golf putting performance. Results support bioinformational theory by demonstrating that LSRT can facilitate visual and kinesthetic MI ability and reiterate the importance of imagery ability to ensure MI is an effective prime for movement execution.

Keywords: bioinformational theory, imagery practice, imagery priming, movement imagery, visual imagery

Motor imagery (MI) is the mental representation of a movement or action without any corresponding body movement (Guillot & Collet, 2005). It is a popular cognitive strategy used to facilitate motor learning and performance (for reviews, see Cumming & Williams, 2012; Holmes, Cumming, & Edwards, 2010). Imagery's diverse nature and wide application means it is of interest to various fields including cognitive psychology, neuropsychology, neurophysiology, neurorehabilitation, motor learning, motor control, physiology, and sport psychology (Cumming & Williams, 2012). However, its impact is influenced by an individual's ability to create and control vivid images (Martin, Moritz, & Hall, 1999). Imagery interventions are more effective for individuals reporting a higher ability to image compared with their lower level counterparts (e.g., Hall, Buckolz, & Fishburne, 1992; Robin et al., 2007). Research has proposed that MI ability will moderate the relationship between what and how individuals image and the achieved outcome (Cumming & Williams, 2012; Martin et al., 1999). Cumming and Williams further suggest that if an individual is not able to form images of particular content or from a certain viewpoint (e.g., image taking a penalty in soccer in a first person perspective by viewing the image through his/her own eyes as if he/she was performing the movement), the potential for using MI to improve this skill will be considerably reduced.

The success of using MI to aid learning and performance is thought to result from the shared brain processes imagery has with movement execution (for reviews, see Grèzes & Decety, 2001; Jeannerod, 2001; Munzert, Lorey, & Zentgraf, 2009). This partial neural overlap suggests MI is somewhat functionally equivalent to motor behavior at the neural level (Johnson, 1982). Through activation of cortical areas during both processes, MI is thought to prime movement execution. Performance is improved through the changes in neural pathways and synapses responsible for actual performance causing them to more correctly activate during execution of the movement. Kosslyn, Ganis, and Thompson (2001) explain that "imaging, making movements might exercise the relevant brain areas . . . which in turn facilitate performance" (p. 639). Similar to imagery, observation has some shared neural overlap with movement execution (for review, see Rizzolatti & Craighero, 2004). When primed using observation, better execution arises when there is greater congruency between the prime and the desired movement. This modulation is attributed to the greater overlap in neural activity occurring (e.g., Brass, Bekkering, & Prinz, 2001). It is similarly argued that MI would more effectively prime movement execution when there is greater overlap of neural activity between the two processes (Cumming & Williams, 2012; Holmes & Collins, 2001; Williams, Cumming, & Edwards, 2011). Because MI ability can influence the effectiveness of MI use, it is postulated that individuals displaying greater imagery

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ability will experience more efficient MI for subsequent execution (Guillot et al., 2008). This congruency between the imagery prime and movement execution is likely to result in a more accurate motor performance.

Although MI ability can influence imagery effectiveness, it has been described as a skill that individuals can continually develop with invested time and effort (Hall, 2001). Using the Movement Imagery Questionnaire (MIQ; Hall & Pongrac, 1983), Rodgers, Hall and Buckolz (1991) reported significant improvements in figure skaters' ease of imaging after 16 weeks of imagery training. As with any skill, efforts are needed to establish effective strategies for improving MI ability, with the eventual goal of developing guidelines for researchers and applied practitioners to follow when working with individuals in various disciplines to facilitate motor learning and performance. However, to date, very little is known about methods to develop MI ability. Moreover, the majority of research has focused on improving imagery ability in individuals who already display a relatively good ability to image.

One method that may improve MI ability is to build images up in layers, gradually generating more complex images by adding information in progressive stages. Nordin and Cumming (2005) revealed that professional dancers employ a layering technique to facilitate the development of vivid images. The dancers described how they begin with a simple image, and then include more details or additional sensory modalities (e.g., a sound or a feeling) with each subsequent layer. A similar layering approach was adopted by Calmels, Holmes, Berthoumieux, and Singer (2004) in their intervention with softball players. The imagery was introduced in five stages, with each stage adding extra details to the imagery scenario. Findings supported this method, as players reported an increase in imagery vividness over the course of the intervention.

Based on Lang's bioinformational theory (Lang, 1979; Lang, Kozak, Miller, Levin, & McLean, 1980), a structured exercise to improve imagery ability is layered stimulus and response training (LSRT). Lang (1979) proposed that emotional images are composed of stimulus, response, and meaning propositions. Stimulus propositions are characteristics of the imagery scenario (e.g., specific details about the competition venue or winning a race). Response propositions can describe the verbal responses (e.g., shout), somatomotor events (e.g., muscle tension), visceral events (e.g., increased heart rate), processor characteristics (e.g., disorientated in time), and sense organ adjustments (e.g., postural changes) an athlete would experience when exposed to the real-life stimulus. Finally, meaning propositions explain the relationship between the stimulus and response propositions to the athlete. It has been suggested that imagery containing response propositions in addition to stimulus propositions can produce more vivid imagery (Lang et al., 1980). Previously employed by Cumming and colleagues (Cumming, Olphin, & Law, 2007; Williams, Cumming, & Balanos, 2010), LSRT initially involves drawing the individual's attention toward specific stimulus details within the imaged scenario that he/she finds relatively easy to image (e.g., seeing the ball toss and then your racket make contact with the ball during a tennis serve), before making the individual aware of additional stimulus propositions and the response and meaning propositions that would also be experienced (e.g., feeling your arm raise, the ball leave your hand, and racket make contact, or feeling confident about the serve). These additional propositions are introduced and added to the original image in separate layers. Unlike Calmels et al.'s. (2004) layering technique, LSRT has been previously confined to a single imagery session, with the intention of having the participant experience more immediate benefits to their MI ability before receiving guided imagery as part of an experimental protocol (Williams et al., 2010). However, until now, research has yet to systematically examine its effectiveness as a technique to improve MI ability.

Literature suggests that LSRT has the potential to not only improve MI ability, but also the execution of the motor skill being imaged. Lang (1979) proposed that the inclusion of response propositions initiates the motor program for the movement being imaged, resulting in elicited physiological responses also known as "efferent leakage." The motor program of a particular movement is thought to be strengthened by the combination of stimulus and response propositions during the imagery, resulting in a more effective prime for subsequent physical performance. Consequently, based on the bioinformational theory, building up stimulus and response propositions in a layered approach could help participants effectively incorporate these elements into an image. The individual may then more easily generate, transform, and maintain the image, which in turn, could lead to greater motor learning or performance. Indeed, greater improvements in performance have been experienced following MI containing stimulus and response propositions compared with stimulus only imagery (e.g., Smith, Holmes, Whitemore, Collins, & Devonport, 2001).

Although such techniques and training exercises that use layered response propositions are being more widely employed during imagery studies within various settings, (e.g., Cumming et al., 2007; Williams et al., 2010), to our knowledge, no study has systematically examined their effectiveness. The initial support found by Calmels et al. (2004) is limited by their study's small sample (N = 4) and quasi-experimental design. No control group was employed; therefore, it is unknown whether improvements in MI ability were due to the process of layering the stimulus and response details or from repeated imagery practice, which has previously been shown to lead to some improvements in MI ability (e.g., Cumming & Ste-Marie, 2001; Rodgers et al., 1991). Additionally, the MI ability improvements resulting from Calmels et al.'s intervention occurred over 28 imagery sessions. Techniques to layer stimulus and response propositions, however, are more commonly used within a condensed time frame, which implies that the benefits are more immediate (e.g., Cumming et al., 2007; Williams et al., 2010). This technique could then be used to boost participants' imagery ability if they fall below a desired criterion (e.g., scoring below a threshold on a self-reported imagery ability questionnaire). It is therefore important to establish whether frequently used LSRT exercises can improve MI ability, and whether any improvements occurring are specific to the imagery content rehearsed in the LSRT exercises, or whether any improvement in MI ability also occurs for more complex motor skills. Finally, despite the assumption that greater MI ability will lead to greater performance, it is yet to be investigated whether improving an individual's MI ability through LSRT will result in imagery use that will facilitate motor performance to a greater extent than for an individual engaging in MI practice.

Based on the unknown capabilities of LSRT, the aim of the intervention was threefold. The first aim was to test the bioinformational theory and investigate whether a four-day LSRT intervention of golf putting imagery could improve specific golf putting MI ability beyond just MI practice. The second aim was to examine whether both these techniques could also improve general MI ability of simple movements and more complex motor skills, as reflected in validated questionnaires and whether LSRT would elicit greater improvements. The final aim of the intervention was to investigate whether any improvements in MI ability, as a result of LSRT and MI practice, could elicit greater improvements in actual golf putting performance compared with a control group comparison and whether LSRT improvements were greater than MI practice. The majority of imagery studies and interventions involve individuals with relatively high imagery ability and often exclude those who fail to meet certain criteria when screened for their imagery ability. It is largely unknown whether individuals with lower imagery ability benefit from imagery training and thus do not need to be excluded from such research. Consequently, this study specifically focused on those with lower MI ability. It was hypothesized that both MI practice and LSRT would result in an increase in golf-specific MI ability. It was also hypothesized that the LSRT group would experience an improvement in general MI ability of basic movements and more complex motor skills. Finally, it was hypothesized that improvements to MI ability resulting from the LSRT would result in an improvement in actual golf putting performance.

Method

Participants

Twenty-four participants (12 females, 12 males) with a mean age of 20.13 years (*SD* = 1.65) participated in the intervention. Participants had either no previous putting experience (n = 10) or putted less than once a year (n = 14). Furthermore, none of the participants had ever received any imagery training before taking part in the intervention and had no direct link with the experimenters.

Equipment

Equipment consisted of a standard length (90-cm) golf putter (Golden Bear Claw Blade), 15 regular-size (4.77 cm in diameter) golf balls (Top Flite), and an artificial Patiograss putting surface 1.405 m wide and 6.25 m in length. To ensure the task was adequately difficult, following pilot testing, the hole situated 2 m away from where all putts were taken was reduced in size to half the size of a regular hole (5.5 cm) and was placed 0.675 m from each side of the putting surface edge.

Imagery Intervention

Participants took part in one of three imagery interventions, which were composed of four sessions over consecutive days. In each session, the participants, irrespective of their imagery intervention, performed five images and then described each image to the researcher after it was performed. To enhance the functional equivalence between the imagery and the putting action at a neural level, as advocated by Holmes and Collins (2001), imagery was performed while holding the putter and in the correct putting stance on the putting mat. Participants were also asked to always image from their preferred visual perspective and to maintain this perspective throughout the intervention. Participants in the VI group were asked to "imagine seeing the golf ball run along the green and gently roll into the hole" whereas participants in the MI and LSRT groups were asked to "imagine yourself correctly and successfully performing the golf putting task." After each image the participants would verbally evaluate their image aloud and detail what aspects of the image they found particularly strong/clear/easy to image and which aspects they found vague/dim/more difficult to image. After this evaluation, participants were asked to repeat the process another four times in the session and compare each image to the previous ones.

The only difference between the LSRT group and the MI group was that a layering approach was used with the LSRT group to try to build the image up and make it as realistic and lifelike as possible. This was done after the initial image evaluation in Session 1 by asking participants to reduce the details in their image so they include only a few stimulus and/or response details that were particularly easy to generate in the second image. For the remaining images, participants added in additional propositions that they believed would enhance the imagery quality. Consequently, over the five images that were performed during the session, participants in the layering group attempted to either build the image up by including even more details and/or by making the details more vivid or lifelike. It is important to note that this process was participant generated and individuals were not directed to incorporate specific propositions by the researcher; rather, it was propositions that the participant felt would make the image more realistic of the actual situation if they were added to the image. Each session was then designed to build on the previous session; in the first image of the session, participants would image the content experienced in the last image of the previous session before then attempting to layer in more stimulus and response propositions. Participants in the MI and VI groups did not include this layered approach and instead each image contained the same propositions throughout. Consequently, the groups were matched as closely as possible in terms of the number of images, the duration of the imagery, and the content and attention given to the imagery.

Measures

Demographic Information. Participants were asked to provide information about their age, gender, putting experience, and whether they had taken part in any previous imagery training.

Specific Imagery Ability. Imagery ability specific to the content of the imagery intervention (i.e., golf putting) was rated using two single items. The first determined how easy it was to *see* the images generated and the second asked how easy it was to *feel* the images generated. Both ratings were made on a 7-point Likert-type scale ranging from 1 (*very hard to see/feel*) to 7 (*very easy to see/feel*). Participants in the VI group answered only the first question, as it was likely that their imagery had no kinesthetic component and we did not want to encourage them to incorporate such feelings during the intervention.

General Motor Imagery Ability. General MI ability was assessed using the Movement Imagery Questionnaire-3 (MIQ-3; Williams et al., 2012) and the skill subscale of the Sport Imagery Ability Questionnaire (SIAQ; Williams & Cumming, 2011). The MIQ-3 was used to assess general motor imagery ability of simple movements. The 12 items measure the visual component of MI from an external (or third person) perspective and an internal (or first person) perspective, as well as the ability to image the kinesthetic component of MI. Four movements (knee lift, jump, arm movement, and waist bend) are imaged in each perspective/modality. For each item, participants read a description of the movement, physically perform the movement, and then image the movement using external visual imagery, internal visual imagery, or kinesthetic imagery. Ease of imaging is then rated on a 7-point Likert-type scale ranging from 1 (*very hard to see/feel*) to 7 (*very easy to see/feel*). Average scores are then calculated for each subscale with a higher score representing a greater ease of imaging. Williams et al. (2012) showed that the MIQ-3 is a valid and reliable questionnaire to assess these different types of MI ability. The questionnaire demonstrated good internal reliability in the current study, both at baseline and postintervention, with Cronbach alpha coefficients above .70 for external visual MI (baseline = .84, posttest = .93), internal visual MI (baseline = .74, posttest = .90), and kinesthetic MI (baseline = .74, posttest = .90).

The SIAQ was used to assess participant's MI ability of more complex skill-related images. The SIAQ is a 15-item questionnaire that assesses how easily individuals can image content reflective of the cognitive and motivational functions of imagery (i.e., skill, strategy, goal, affect, and mastery images). Participants image each item and rate the ease with which they are able to do this on a 7-point Likert-type scale ranging from 1 (*very hard to image*) to 7 (*very easy to image*). Average scores are calculated for each subscale, with a higher score representing greater imagery ability. The SIAQ has been identified as a valid and reliable questionnaire with good psychometric properties (Williams & Cumming, 2011). For the purpose of the current study only the skill subscale was used to reflect MI ability as this content was most similar to that used in the imagery intervention. It demonstrated good internal reliability at baseline and postintervention with Cronbach alpha coefficients being above .70 (baseline = .80, posttest = .94).

Putting Performance. Performance of the golf putting trial at baseline and following the intervention was assessed in two ways. Firstly, the number of putts successfully sunk was totaled, and secondly, the average distance from the hole in centimeters was calculated. Distance was measured using a tape measure from the nearest part of the ball to the lip of the hole. If an attempt overshot the putting mat, it was awarded a score of 300 cm because a change in surface prevented a more accurate measure of the ball's distance from the hole. Distance and total number of putts sunk were both recorded by the researcher.

Posttrial Evaluation Form. Developed from items used in previous studies (e.g., Ramsey, Cumming, & Edwards, 2008), participants completed a posttrial evaluation form following each golf putting trial. The first item asked participants to report the extent they were trying to putt the ball as close to the hole as possible (ranging from 1 = *not at all* to 7 = *before every putt*). The second item asked participants to indicate what, if any, additional psychological strategies they used to assist in their performance. Following the postintervention trial, participants also indicated to what extent they: 1) incorporated the imagery they were instructed to use during the putting task; 2) performed the imagery as instructed; and 3) used the same visual perspective they had adopted during the week's imagery exercises. Ratings were made on 7-point Likert type scales ranging from 1 (*not at all/not at all/never the same perspective*) to 7 (*before every putt/exactly/always the same perspective*).

Imagery Session Manipulation Checks. Following each imagery session, participants indicated the extent they had been engaged in the imagery (rated as a percentage between 0 and 100%) and the extent they imaged the scenario as instructed (rated between 1 = *not at all* and 7 = *completely*).

Postintervention Evaluation. At the end of the intervention, participants completed an evaluation form indicating the extent the imagery sessions had been helpful with regards to seeing and feeling the golf putting action, and enhancing the vividness and clarity of this movement (rated between 1 = *very unhelpful* and 7 = *very helpful*). The final item asked participants which visual perspective they had adopted during the week's imagery sessions. Participants selected either an internal/first person perspective or an external/third person perspective.

Procedures

Recruitment and Screening. Following ethical approval from the university where the authors are based, potential participants were explained the nature of the study by one of the investigators. Those interested in participating signed a consent form and were screened for their MI ability by completing the SIAQ skill subscale to identify those who displayed a relatively low MI ability of complex skills. Participants eligible to take part in the intervention were those who displayed an average score of less than 5 (*somewhat easy to image*) and were novice golfers. Of the 311 participants who completed the SIAQ, 43 met the screening criteria to participate in the study. Of these, 24 were willing to take part in the intervention, which consisted of being tested individually during five separate visits to the laboratory on consecutive days. These visits comprised of a baseline visit and four imagery sessions.

Baseline Visit. Participants were provided with a definition of mental imagery, along with descriptions of external visual imagery, internal visual imagery, and kinesthetic imagery as used in previous studies (e.g., Williams et al., 2011). Participants then completed the MIQ-3 and golf putting task. Because participants were all novice golfers, they were given some brief instructions of how to hold the putter and the type of putting action they should perform. The putting task involved taking 15 putts in 3 blocks of 5. Participants were instructed to putt the ball as close to the hole as possible with the aim of successfully putting as many of the 15 attempts as they could. Before the 15 putts, participants were first given three practice attempts. Following the putting task, participants completed the posttrial evaluation. The duration of the baseline visit took no longer than 1 hr.

Imagery Sessions. Each imagery intervention session composed of five images and lasted approximately 15 min. Before attending the first of these visits, participants were randomly assigned to one of three intervention groups with an even gender split: (1) VI practice group (n = 8; 4 male), (2) MI practice group (n = 8; 4 male), or (3) LSRT group (n = 8; 4 male). Following each imagery intervention session, all participants rated their specific imagery ability.

Postintervention Test. Immediately after the fourth imagery intervention session, a posttest was conducted. Participants first completed the golf putting task for a second time before completing the posttrial evaluation form. Then, participants completed the MIQ-3 and SIAQ skill subscale before being thanked for their participation and debriefed on the nature of the study. Completion of the postintervention test took no longer than 1 hr.

Results

Preliminary Analyses

Preliminary analyses were conducted to investigate whether any of the main analysis could have been influence by differences between groups, such as differences in task engagement, additional psychological skill usage, and imagery usage throughout the intervention.

Posttrial Evaluations. Participants reported a mean score of 6.67 (SD = 0.56) during the baseline trial and 6.71 (SD = 0.55) during the postintervention trial in the degree to which they tried to get the ball as close to the hole as possible. A 3 (experimental group) × 2 (time) mixed design ANOVA revealed that this rating did not significantly differ between the groups or change from baseline to postintervention. Twelve participants reported using a psychological strategy to assist their performance (goal setting, n = 6; self-talk, n = 6) during the baseline golf putting trial. Furthermore, during the postintervention golf putting trial six participants reported using an additional psychological strategy (goal setting, n = 4; own imagery, n = 2). Participants reported a mean score of 6.79 (SD = 0.59) for how frequently they incorporated their imagery during the postintervention golf putting trial, a mean score of 6.29 (SD = 0.55) for the extent it was performed as instructed, and a mean score of 6.54 (SD = 0.51) for the extent it was conducted in the same perspective as the week's imagery exercises. Results of three one-way ANOVAs revealed that this did not significantly differ between any of the groups. Posttrial evaluation results for each group are reported in Table 1.

Imagery Session Manipulation Checks. During the four imagery sessions, participants reported that on average they engaged in imagery between 79% and 94% of the time. Although results of a 3 (experimental group) × 4 (session) mixed design ANOVA revealed no significant effect for group and no session × group interaction, there was a significant effect for session, $F(2.03, 42.52) = 11.93$, $p < .001$, $\eta_p^2 = .36$, $1 - \beta = .99$. Post hoc analyses revealed that participants engaged in the third and fourth session significantly more than the first session. When investigating any differences in the extent participants imaged as instructed, a 3 (experimental group) × 4 (session) mixed design ANOVA revealed no significant effect for session, group, and no session × group interaction. Means and standard deviations of the imagery session manipulation checks are reported in Table 2.

Postintervention Evaluation. All participants indicated that they had adopted an internal visual imagery perspective during the imagery sessions. Three one-way ANOVAs were evaluated with a more conservative alpha level ($p < .017$) to determine if any differences existed

Table 1 Posttrial Evaluation According to Group

			VI	MI	LSRT
(a) Baseline and Postintervention					
Extent aiming for the hole	Baseline	*M*	6.63	6.75	6.62
(1 = *not at all*, 7 = *before every putt*)		*SD*	0.52	0.46	0.74
	Postintervention	*M*	6.75	6.75	6.63
		SD	0.46	0.46	0.74
Additional strategies used	Baseline				
	Goal Setting	*n*	2	2	2
	Self-Talk	*n*	1	3	2
	Postintervention				
	Goal Setting	*n*	1	1	2
	Own Imagery	*n*	1	1	0
(b) During the postintervention golf putting trial, to what extent was your imagery					
. . . employed (1 = *not at all*, 7 = *before every putt*)		*M*	6.38	6.63	7.00
		SD	0.74	0.74	0.00
. . . performed as instructed (1 = *not at all*, 7 = *exactly*)		*M*	5.75	6.25	6.00
		SD	1.04	0.89	0.76
. . . the same perspective as the weekly sessions (1 = *never the same*, 7 = *always the same*)		*M*	6.13	6.50	6.33
		SD	0.83	0.53	0.70

Note. VI = visual imagery practice group, MI = motor imagery practice group, LSRT = layered stimulus response training group.

Table 2 Imagery Session Manipulation Checks

	Session 1		Session 2		Session 3		Session 4	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Engaged in imagery (0–100%)								
VI	88.75	6.41	90.00	9.26	92.50*	7.07	93.75*	5.18
MI	78.75	17.27	87.50	7.07	91.25*	8.35	92.50*	7.07
LSRT	83.75	11.72	88.75	6.41	90.00*	0.00	92.50*	4.63
Imaged as instructed (1 = *not at all*, 7 = *exactly*)								
VI	5.75	0.87	5.63	0.74	5.75	0.87	5.88	0.83
MI	6.25	0.46	6.00	0.53	6.38	0.52	6.25	0.71
LSRT	5.75	0.46	6.25	0.46	6.50	0.53	6.38	0.52

Note. * = significantly greater than Session 1 ($p < .001$). VI = visual imagery practice group, MI = motor imagery practice group, LSRT = layered stimulus response training group.

in perceptions of how well the imagery sessions helped participants to see and feel the golf putting action and enhance the vividness and clarity of the movement. For seeing the action, results revealed a significant difference between groups, $F(2, 21) = 24.11$, $p < .001$, $\eta_p^2 = .70$, $1 - \beta = 1.00$. Post hoc analyses revealed that participants who experienced sessions imaging the putting action (MI practice: $M = 6.00$, $SD = 0.93$; LSRT: $M = 6.50$, $SD = 0.53$) reported these images as being significantly more helpful than the VI practice sessions ($M = 3.50$, $SD = 1.20$). Results also revealed a significant difference for feeling the putting action, $F(2, 21) = 45.03$, $p < .001$, $\eta_p^2 = .81$, $1 - \beta = 1.00$, and enhancing its vividness and clarity $F(2, 21) = 17.46$, $p < .001$, $\eta_p^2 = .62$, $1 - \beta = .99$.

Post hoc analyses revealed that the LSRT sessions (M = 6.50, SD = 0.76) were significantly more helpful than the MI sessions (M = 5.38, SD = 0.52), which in turn were significantly more helpful than the VI sessions (M = 2.50, SD = 1.20). Additionally, the LSRT sessions (M = 6.25, SD = 0.71) enhanced the vividness and clarity of the imagery significantly more than the VI (M = 4.25, SD = 0.46) and MI (M = 4.63, SD = 0.92) sessions.

Main Analyses

Specific Imagery Ability. A 3 (experimental group) × 4 (session) mixed design ANOVA was conducted to assess ease of being able to see the golf specific imagery performed during the imagery sessions, and a 2 (experimental group) × 4 (session) mixed design ANOVA was conducted to assess ease of being able to feel the golf putting action for the MI and LSRT groups. The VI group was not included in this latter analysis because they were not encouraged to incorporate kinesthetic sensations. A more conservative alpha level ($p < .025$) was used when analyzing the results. Results for being able to see golf specific imagery ability revealed a significant effect for time, $F(3, 63) = 18.04$, $p < 001$, $\eta_p^2 = .46$, $1 - \beta = 1.00$. There was no significant effect for group and no significant time × group interaction. Bonferroni post hoc analyses revealed that although there were no differences between the three groups, participants found it significantly easier to see their respective imagery scenario during Sessions 3 (M = 5.92, SD = 1.64) and 4 (M = 6.00, SD = 0.93) compared with Session 2 (M = 5.29, SD = 1.12), which was in turn significantly easier to see compared with Session 1 (M = 4.79, SD = 0.72).

For being able to feel golf specific MI ability, results also revealed a significant effect for time, $F(3, 42) = 11.23$, $p < 001$, $\eta_p^2 = .45$, $1 - \beta = .87$. However, for this analysis there was a significant effect for group, $F(1, 14) = 20.87$, $p < 001$, $\eta_p^2 = .60$, $1 - \beta = .99$, but no significant time × group interaction. Post hoc analyses revealed that participants in both groups found it significantly easier to feel the golf putting action during Sessions 3 (M = 5.31, SD = 0.95) and 4 (M = 5.69, SD = 0.87) compared with Sessions 1 (M = 4.19, SD = 1.33) and 2 (M = 4.75, SD = 0.86). Additionally, during each imagery session, participants in the LSRT group (M = 5.51, SD = 0.77) were able to image the feeling of the golf putting action more easily than those in the MI group (M = 4.41, SD = 0.87). Specific imagery ability means during each imagery session for the different groups are reported in Figure 1.

General Motor Imagery Ability. hree separate 3 (experimental group) × 2 (time) mixed design ANOVAs with a more conservative alpha level ($p < .017$), were used to investigate any differences in MIQ-3 external visual, internal visual, and kinesthetic MI ability before and after the imagery intervention. Results revealed no significant main effect for time or group, and no time × group interaction for external visual MI. Results of the internal visual MI ANOVA revealed a significant effect for time, $F(1, 21) = 28.15$, $p < .001$, $\eta_p^2 = .57$, $1 - \beta = .99$, but no significant effect for group or time × group interaction. Post hoc analyses revealed that participants reported a significant increase in internal visual MI ability following the imagery intervention (M = 5.19, SD = 1.10) compared with baseline (M = 4.27, SD = 0.94). Results of the kinesthetic MI ability ANOVA revealed a significant effect for time, $F(1, 21) = 13.23$, $p = .002$, $\eta_p^2 = .39$, $1 - \beta = .94$, and a significant time × group interaction, $F(2, 21) = 9.29$, $p = .001$, $\eta_p^2 = .47$, $1 - \beta = .96$. There was no significant effect for group. Post hoc analyses revealed that following the imagery intervention the LSRT group reported significantly greater kinesthetic MI scores (M = 5.75, SD = 0.79) compared with the VI group (M = 4.09, SD = 1.17). The LSRT group also reported significantly higher kinesthetic MI imagery following

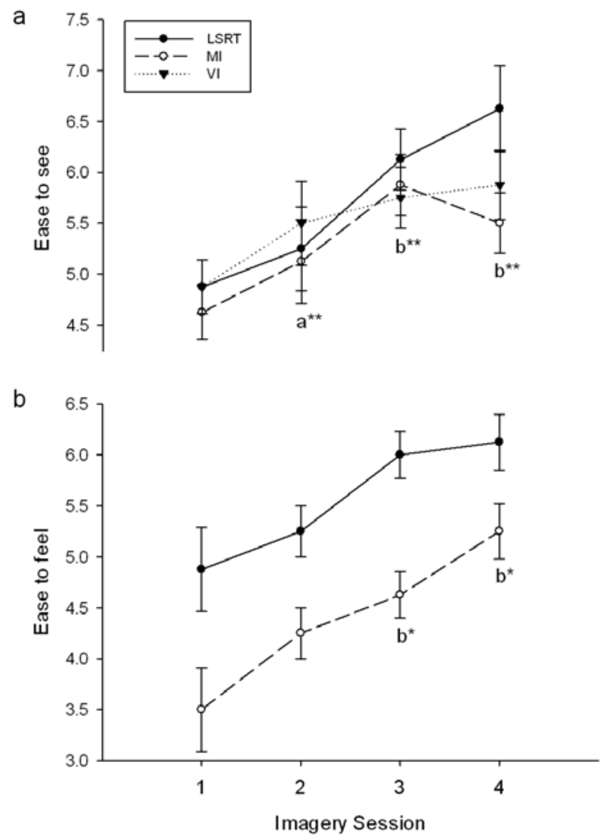

Figure 1 — (a) Mean ease of seeing golf-specific images. (b) Mean ease of feeling golf-specific images. The LSRT group reported significantly greater feeling scores than the MI practice group ($p < .001$). Letters represent significant effects for time (*$p < .05$; **$p < .001$). a = significantly greater than Session 1, b = significantly greater than Sessions 1 and 2. Error bars represent mean standard errors. VI = visual imagery practice group, MI = motor imagery practice group, LSRT = layered stimulus response training group.

the intervention compared with their baseline scores (*M* = 3.78, *SD* = 0.91).

A 3 (experimental group) × 2 (time) mixed design ANOVA was conducted to assess MI ability of more complex skills (SIAQ subscale) before and after the imagery intervention. Results revealed a significant effect for time, $F(1, 21) = 18.14$, $p < .001$, $\eta_p^2 = .46$, $1 - \beta = .98$, and a significant time × group interaction, $F(2, 21) = 9.64$, $p = .001$, $\eta_p^2 = .48$, $1 - \beta = .96$. There was no significant effect for group. Post hoc analyses revealed that the LSRT group's skill MI ability significantly improved from baseline (*M* = 3.33, *SD* = 0.69) to postintervention (*M* = 5.88, *SD* = 0.64). Moreover, even though there were no differences at baseline, at postintervention the LSRT group reported significantly higher skill MI ability compared with the VI (*M* = 3.71, *SD* = 1.89) and MI (*M* = 4.17, *SD* = 0.96) groups. Means and standard deviations of all groups' MIQ-3 and SIAQ scores are reported in Table 3.

Golf Putting Performance. Results revealed that 12% of baseline putts and 5% of postintervention putts overshot the hole. Two separate 3 (experimental group) × 2 (time) mixed design ANOVAs using a more conservative alpha level ($p < .025$) were calculated to determine any changes in number of successful putts sunk and distance from the hole for the groups following the imagery intervention. For number of successful putts sunk, results revealed no significant effect for time or group. However, there was a significant time × group interaction, $F(2, 21) = 6.41$, $p = .007$, $\eta_p^2 = .38$, $1 - \beta = .86$. Post hoc analyses revealed that despite there being no differences between groups at baseline, the LSRT group successfully putted significantly more attempts following the intervention (*M* = 2.63, *SD* = 0.91) compared with the VI group (*M* = 0.50, *SD* = 0.76). This was also a significant improvement in performance compared with baseline (*M* = .075, *SD* = 1.04). For distance from the hole, results revealed a significant effect for time, $F(1, 21) = 16.42$, $p = .001$, $\eta_p^2 = .44$, $1 - \beta = .97$, and a significant time × group interaction, $F(2, 21) = 4.70$, $p = .021$, $\eta_p^2 = .31$, $1 - \beta = .82$. However, there was no significant effect for group. Post hoc analyses revealed that although there were no differences between groups at baseline, the LSRT group's putting attempts were significantly closer to the hole following the intervention (*M* = 22.26, *SD* = 10.00) compared with the VI group (*M* = 79.35, *SD* = 56.60). The LSRT group were also significantly closer to the hole following the intervention than at baseline (*M* = 81.04, *SD* = 49.31). Means and standard errors for all groups' golf putting performance are reported in Figure 2.

Discussion

To test bioinformational theory the current study investigated the effects of LSRT compared with MI practice and VI practice. Specifically, the effects of MI practice and LSRT on specific and general MI ability was compared with VI practice and any differences between LSRT and MI practice were examined. Further, it investigated whether any improvements in MI ability were accompanied by improvements in golf putting performance compared with a VI control group comparison. As well as increasing specific MI ability (i.e., of a golf putting

Table 3 MIQ-3 and SIAQ Scores at Baseline and Postintervention

	VI		MI		LSRT		All Groups	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
EVI								
Baseline	4.34	1.51	4.47	0.99	4.28	0.91	4.36	1.12
Post	4.46	1.48	4.84	1.39	5.25	1.38	4.75	1.42
IVI								
Baseline	4.47	1.09	3.94	0.93	4.41	0.79	4.27	0.94
Post	4.81	1.19	4.81	0.94	5.94	0.40	5.19[a]**	1.10
KI								
Baseline	4.22	1.01	4.19	0.73	3.78[b]**	0.91	4.06	0.88
Post	4.09[b]*	1.17	4.59	1.36	5.75	0.79	4.83	1.29
Skill								
Baseline	3.71	0.90	3.67	1.26	3.33[b]**	0.69	3.57	0.95
Post	3.79[b]**	1.26	4.17[b]*	0.96	5.88	0.64	4.61	1.32

Note. [a] = significantly greater than baseline, [b] = significantly greater than layered imagery postintervention (**p* < .01; ***p* < .001). VI = visual imagery practice group, MI = motor imagery practice group, LSRT = layered stimulus response training group. EVI = external (3rd person) visual imagery, IVI = internal (1st person) visual imagery, KI = kinesthetic imagery, Skill = skill imagery.

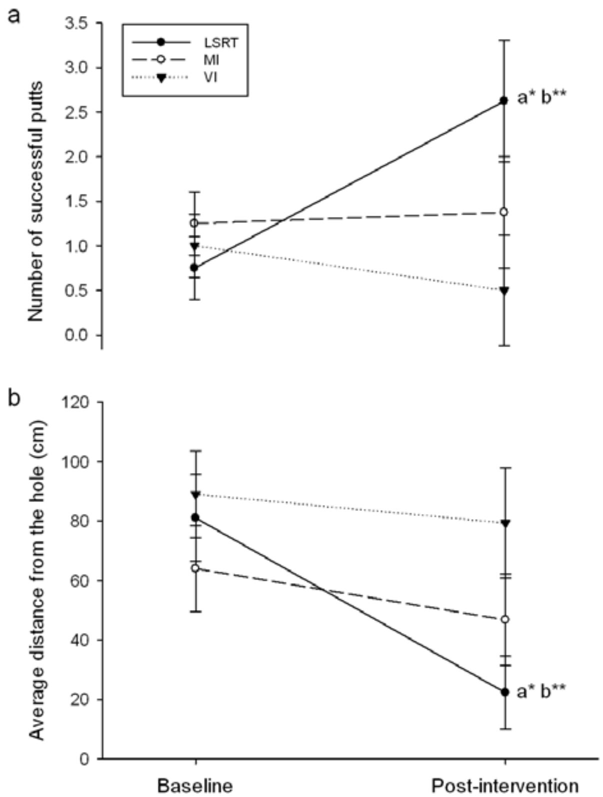

Figure 2 — (a) Total number of successful putts. (b) Average distance from the hole. Letters represent significant differences (*$p < .01$; **$p < .001$). a = significantly different to the VI group postintervention score. b = significantly different to baseline. Error bars represent mean standard errors. VI = visual imagery practice group, MI = motor imagery practice group, LSRT = layered stimulus response training group.

action), it was also predicted that LSRT would produce an increase in MI ability for imaging other simple and more complex movements and skills. Finally, it was hypothesized that improvements to MI ability resulting from LSRT would result in an improvement in golf putting performance compared with MI and VI practice.

Manipulation check results revealed no significant group differences in the extent participants aimed for the hole or used any additional psychological strategies during the putting trials. High ratings and no significant differences in other manipulation checks revealed that all participants were consistent in using their preferred visual perspective, imaged the scenario frequently and as instructed. This suggests participants followed the instructions of the intervention increasing the likelihood that group differences in the main analyses are due to the nature of the imagery intervention received (i.e., MI or VI practice, or LSRT) rather than factors related to social desirability.

All groups engaged in their imagery significantly more during Sessions 3 and 4 compared with Sessions 1 and 2. This suggests they were able to maintain the image for a longer period of time as the intervention progressed. Kosslyn (1994) explains that the imagery process involves generating the image before transforming and maintaining it and it has been postulated that an individual's imagery ability is likely to capture their proficiency in performing all three of these processes (Williams & Cumming, 2011). Therefore, it can be suggested that imagery practice could improve individuals' maintenance imagery ability.

Further supporting previous research that imagery practice can improve MI ability (e.g., Cumming & Ste-Marie, 2001; Rodgers et al., 1991), participants' found it easier to see their specific intervention image during Session 2, and feel their specific intervention image during Session 3. Our results replicate previous research that an improvement in kinesthetic MI ability requires more practice than visual MI ability. Moreover, they extend findings by demonstrating imagery practice can also improve lower levels of imagery ability.

Interestingly, the LSRT group found it significantly easier to feel the golf putting action compared with the MI practice group. Because ease of feeling the golf putting action was not measured before the first imagery session, we cannot conclude that the LSRT improved kinesthetic MI in one session. However, the similarity between groups in kinesthetic MI measured by the MIQ-3 at baseline suggests that the technique of LSRT facilitates an individual's kinesthetic imagery process by making it easier to create and control these images. Nonetheless, our findings demonstrate that with only a few practice attempts, participants with lower imagery ability can experience improvements in imagining both visual and kinesthetic components of an image.

Regarding general movement images, all participants reported improvements in internal visual but not external visual MI ability as measured by the MIQ-3. This might be explained in part by the participants' preference to image from an internal visual perspective. These findings indicate that imagery practice is likely to only improve visual MI ability in the perspective participants adopt. Therefore, improvements in VI may not generalize to the other visual perspective and supports the need to ensure manipulation checks are carried out in imagery studies to consider the effect of imagery perspective.

Interestingly, although participants in the MI practice group experienced improvements in specific kinesthetic MI ability, kinesthetic MI ability of MIQ-3 movements only improved for LSRT participants. Similarly, only LSRT participants experienced an increase in SIAQ skill imagery ability suggesting that only LSRT is able to elicit improvements in more complex motor images. The SIAQ assesses ease of imaging which is a combination of visual and kinesthetic imagery ability (Williams & Cumming, 2011). Therefore from our findings, it can be suggested that MI practice may only transfer to improve visual MI ability whereas LSRT is able to elicit improvements in both visual and kinesthetic MI ability.

Most importantly, improving imagery resulted in an improvement in motor performance of a novel golf putting task. This was reflected in both average distance from the hole and the total number of successful putts. However, it was only participants who received LSRT who experienced this improvement and not the MI or VI practice groups. This is the first study to demonstrate that although MI practice can lead to an improvement in MI ability of the task; this may not benefit subsequent performance of the task. Results from the LSRT group, however, revealed that by using LSRT for four days, even in the absence of physical practice, individuals are able to use this to improve their performance of a novel motor task. Previous research revealed that high rates of imagery used with very little physical practice can produce similar performance improvements to when using high rates of physical practice alone (Allami, Paulignan, Brovelli, & Boussaoud, 2008). Our findings support the effect of imagery by demonstrating that through using LSRT, it can also improve performance in the absence of any physical practice.

A possible explanation as to why the MI practice group did not experience any improvements in golf putting performance is that the image generated may not have been an accurate reflection of the movement pattern necessary for successful performance. Because participants did not receive any practice attempts during the intervention, they were not able to receive any feedback with regards to whether the image they were repeatedly practicing was a correct representation. Therefore, during the posttest, the imagery generated may have elicited an inaccurate mental representation of successful performance (e.g., imaging a swing with too much force). In this case, the imagery could have been serving as an inaccurate prime. Participants in the LSRT group, however, may have experienced an improvement in their ability to inspect and transform their imagery, which they then used in the posttest to help with their putting performance. For example, if they hit the ball beyond the hole in one attempt, they could use the LSRT exercises to generate the previous image of hitting the ball but transform it so the swing action was with slightly less force to more accurately represent the movement that was required for a successful putt. Once they experienced a more successful putt following an image, they may have been able to inspect all subsequent images to a greater extent to ensure that they match the desired image as closely as possible. Based on the outcome of each previous putt, LSRT participants may therefore have been able to alter their MI content to image a more successful prime. This suggestion is reinforced by the postintervention evaluation that revealed those in LSRT group perceived their imagery sessions as being more helpful in feeling the correct putting action and enhancing its vividness and clarity. As well as improving the vividness of the image, the LSRT may have helped participants chunk propositions together to make the accurate image easier to generate.

Despite this study's significant contribution to literature, there are limitations to the study that should be acknowledged. Although findings add to our understanding of the mechanisms underlying MI ability's effectiveness on motor performance, all measures of imagery ability were self-reported and assessed ease of imaging. Furthermore a small percentage of putts that overshot the matt could not be accurately measured. Future research should incorporate other behavioral measures such as chronometric assessment to determine whether increases in imagery ability are also reflected in more objective measures of imagery ability. Moreover, research should also investigate the influence of LSRT on imagery vividness as well as ease of imaging to see whether this technique has also has an impact on vividness given its central component of bioinformational theory. To gain more insight into the neural mechanism adaptations as a result of LSRT, we suggest future research investigates what changes in neural activity occur during MI and performance execution as a result of LSRT. Despite using self-report assessments of MI ability that only assess ease of imaging, LSRT can still improve participants' subsequent motor performance of a novel task over a few days in the absence of any physical practice.

We also encourage researchers from various disciplines to continue investigating how imagery ability can be improved to gain greater performance outcomes of a motor task: firstly, whether similar effects can be obtained for individuals with higher levels of imagery ability or whether there is a ceiling effect. Additionally, it can be investigated whether LSRT can bring about changes in other motor tasks and be reflected in other measures of performance (e.g., movement kinematics). Finally, and perhaps most importantly, it should be investigated whether LSRT benefits can be retained by participants to bring about more permanent changes in imagery ability or whether this is lost after a few days or weeks.

Importantly, findings of this research have large implications for both research and applied settings. Firstly, imagery researchers often screen participants for their imagery ability and establish questionnaire cut-off scores that participants must exceed to participate. This intervention supports the notion that imagery may not be effective for individuals who score below 5 on these questionnaires. However, instead of excluding these participants, we suggest exposing them to LSRT to improve their imagery ability and thus retain them in the study. Scores below 5 can be very quickly improved in a matter of days. Our findings also support the SIAQ as a screening tool for MI ability as participants scoring below 5 experienced no benefits from imagery, but benefits were experienced for LSRT participants whose scores of the SIAQ were higher during the posttest. Findings also demonstrate that by using LSRT before a MI experiment, there will be an increased likelihood of witnessing an effect as a result of the imagery. Alternatively, if no effects are found, researchers can be more confident that this is not a result of the participants having low imagery ability. Finally, imagery is becoming a more popular and cost-effective technique to use in the rehabilitation setting with stroke and spinal injury patients to improve motor performance (e.g., Jackson, Lafleur, Malouin, Richards, & Doyon, 2001; Malouin, Belleville, Richards, Desrosiers

& Doyon, 2004). By using LSRT, the recipients of the imagery intervention are more likely to employ a more accurate prime of the movement they want to physically perform.

In conclusion, to our knowledge, this is the first study that has systematically investigated the effects of LSRT and MI and VI practice on participants' specific and general imagery ability, and whether any improvements can lead to improvements in motor performance. Results show that following MI practice, individuals with lower imagery ability can experience improvements in being able to see images in two days and being able to feel the images in three days. Four days of MI or VI practice can also improve visual MI ability of simple movements, from a perspective congruent with that adopted during the imagery practice. Importantly, unlike MI or VI practice, LSRT can also lead to improvements in general skill and kinesthetic MI ability, and subsequence motor performance of a novel task (in this instance, golf putting). Therefore, by employing LSRT, MI ability can be improved and elicit a more effective prime for correct motor planning and performance.

Acknowledgments

This research was funded by the Association for Applied Sport Psychology.

References

Allami, N., Paulignan, Y., Brovelli, A., & Boussaoud, D. (2008). Visuo-motor learning with combination of different rates of motor imagery and physical practice. *Experimental Brain Research, 184,* 105–113. PubMed doi:10.1007/s00221-007-1086-x

Brass, M., Bekkering, H., & Prinz, W. (2001). Movement observation affects movement execution in a simple response task. *Acta Psychologica, 106,* 3–22. PubMed doi:10.1016/S0001-6918(00)00024-X

Calmels, C., Holmes, P., Berthoumieux, C., & Singer, R.N. (2004). The development of movement imagery vividness through a structured intervention in softball. *Journal of Sport Behavior, 27,* 307–322.

Cumming, J., Olphin, T., & Law, M. (2007). Self-reported psychological states and physiological responses to different types of motivational general imagery. *Journal of Sport & Exercise Psychology, 29,* 629–644. PubMed

Cumming, J., & Ste-Marie, D.M. (2001). The cognitive and motivational effects of imagery training: A matter of perspective. *The Sport Psychologist, 15,* 276–287.

Cumming, J., & Williams, S.E. (2012). Imagery: The role of imagery in performance. In S. Murphy (Ed.), *Handbook of Sport and Performance Psychology* (pp. 213–232). New York, NY: Oxford University Press.

Grèzes, J., & Decety, J. (2001). Functional anatomy of execution, mental simulation, observation, and verb generation of actions: a meta-analysis. *Human Brain Mapping, 12,* 1–19. PubMed doi:10.1002/1097-0193(200101)12:1<1::AID-HBM10>3.0.CO;2-V

Guillot, A., & Collet, C. (2005). Contribution from neurophysiological and psychological methods to the study of motor imagery. *Brain Research. Brain Research Reviews, 50,* 387–397. PubMed doi:10.1016/j.brainresrev.2005.09.004

Guillot, A., Collet, C., Nguyen, V.A., Malouin, F., Richards, C., & Doyon, J. (2008). Functional neuroanatomical networks associated with expertise in motor imagery. *NeuroImage, 41,* 1471–1483. PubMed doi:10.1016/j.neuroimage.2008.03.042

Hall, C.R. (2001). Imagery in sport and exercise. In R.N. Singer, H.A. Hausenblas, & C.M. Janelle (Eds.), *The handbook of sport psychology* (2nd ed., pp. 529–549). New York: John Wiley & Sons Inc.

Hall, C.R., Buckolz, E., & Fishburne, G. (1992). Imagery and the acquisition of motor skills. *Canadian Journal of Sport Sciences, 17,* 19–27. PubMed

Hall, C.R., & Pongrac, J. (1983). *Movement imagery questionnaire*. London, Ontario: University of Western Ontario.

Holmes, P.S., & Collins, D.J. (2001). The PETTLEP approach to motor imagery: A functional equivalence model for sport psychologists. *Journal of Applied Sport Psychology, 13,* 60–83. doi:10.1080/10413200109339004

Holmes, P.S., Cumming, J., & Edwards, M.G. (2010). Movement imagery, observation, and skill. In A. Guillot & C. Collet (Eds.), *The neurophysiological foundations of mental and motor imagery* (pp. 245–269). Oxford, UK: Oxford University Press.

Jackson, P.L., Lafleur, M., Malouin, F., Richards, C.L., & Doyon, J. (2001). Potential role of mental practice using motor imagery in neurological rehabilitation. *Archives of Physical Medicine and Rehabilitation, 82,* 1133–1141. PubMed doi:10.1053/apmr.2001.24286

Jeannerod, M. (2001). Neural simulation of action: A unifying mechanism for motor cognition. *NeuroImage, 14,* 103–109. PubMed doi:10.1006/nimg.2001.0832

Johnson, P. (1982). The functional equivalence of imagery and movement. *The Quarterly Journal of Experimental Psychology, 34,* 349–365. PubMed doi:10.1080/14640748208400848

Kosslyn, S.M. (1994). *Image and brain: The resolution of the imagery debate*. Cambridge, MA: MIT Press.

Kosslyn, S.M., Ganis, G., & Thompson, W.L. (2001). Neural foundations of imagery. *Nature Reviews. Neuroscience, 2,* 635–642. PubMed doi:10.1038/35090055

Lang, P.J. (1979). A bio-informational theory of emotional imagery. *Psychophysiology, 16,* 495–512. PubMed doi:10.1111/j.1469-8986.1979.tb01511.x

Lang, P.J., Kozak, M.J., Miller, G.A., Levin, D.N., & McLean, A., Jr. (1980). Emotional imagery: Conceptual structure and pattern of somato-visceral response. *Psychophysiology, 17,* 179–192. PubMed doi:10.1111/j.1469-8986.1980.tb00133.x

Malouin, F., Belleville, S., Richards, C.L., Desrosiers, J., & Doyon, J. (2004). Working memory and mental practice outcomes after stroke. *Archives of Physical Medicine and Rehabilitation, 85,* 177–183. PubMed doi:10.1016/S0003-9993(03)00771-8

Martin, K.A., Moritz, S.E., & Hall, C.R. (1999). Imagery use in sport: A literature review and applied model. *The Sport Psychologist, 13,* 245–268.

Munzert, J., Lorey, B., & Zentgraf, K. (2009). Cognitive motor processes: the role of motor imagery in the study of motor representations. *Brain Research. Brain Research Reviews, 60,* 306–326. PubMed doi:10.1016/j.brainresrev.2008.12.024

Nordin, S.M., & Cumming, J. (2005). Professional dancers describe their imagery: Where, when, what, why and how. *The Sport Psychologist, 19,* 395–416.

Ramsey, R., Cumming, J., & Edwards, M.G. (2008). Exploring a modified conceptualisation of imagery direction and golf putting performance. *International Journal of Sport and Exercise Psychology, 6,* 207–223. doi:10.1080/1612197X.2008.9671862

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience, 27,* 169–192. PubMed doi:10.1146/annurev.neuro.27.070203.144230

Robin, N., Dominique, L., Toussaint, L., Blandin, Y., Guillot, A., & Le Her, M. (2007). Effect of motor imagery training on service return accuracy in tennis: The role of imagery ability. *International Journal of Sport and Exercise Psychology, 5*(2), 175–186. doi:10.1080/1612197X.2007.9671818

Rodgers, W., Hall, C., & Buckolz, E. (1991). The effect of an imagery training program on imagery ability, imagery use, and figure skating performance. *Journal of Applied Sport Psychology, 3,* 109–125. doi:10.1080/10413209108406438

Smith, D., Holmes, P., Whitemore, L., Collins, D., & Devonport, T. (2001). The effect of theoretically-based imagery scripts on field hockey performance. *Journal of Sport Behavior, 24,* 408–419.

Williams, S.E., & Cumming, J. (2011). Measuring athlete imagery ability: The Sport Imagery Ability Questionnaire. *Journal of Sport & Exercise Psychology, 33,* 416–440. PubMed

Williams, S.E., Cumming, J., & Balanos, G.M. (2010). The use of imagery to manipulate challenge and threat appraisal states in athletes. *Journal of Sport & Exercise Psychology, 32,* 339–358. PubMed

Williams, S.E., Cumming, J., & Edwards, M.G. (2011). Does the functional equivalence between movement imagery, observation, and execution influence imagery ability? Investigating different modes of MIQ-R delivery. *Research Quarterly for Exercise and Sport, 82,* 555–564. PubMed doi:10.5641/027013611X13275191444224

Williams, S.E., Cumming, J., Ntoumanis, N., Nordin-Bates, S. M., Ramsey, R., & Hall, C. (2012). Further validation and development of the Movement Imagery Questionnaire. *Journal of Spor1t & Exercise Psychology, 34,* 621–646. PubMed

Manuscript submitted: May 26, 2012
Revision accepted: October 29, 2012