Simultaneous and Alternate Action Observation and Motor Imagery Combinations Improve Aiming Performance

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Abstract

Motor imagery (MI) and action observation (AO) are techniques that have been shown to enhance motor skill learning. While both techniques have been used independently, recent research has demonstrated that combining action observation and motor imagery (AOMI) promotes better outcomes. However, little is known about the most effective way to combine these techniques. This study examined the effects of simultaneous (i.e., observing an action whilst imagining carrying out the action concurrently) and alternate (i.e., observing an action and then doing imagery related to that action consecutively) AOMI combinations on the learning of a dart throwing task. Participants (n=50) were randomly allocated to one of five training groups: action observation (AO), motor imagery (MI), simultaneous action observation and motor imagery (S-AOMI), alternate action observation and motor imagery (A-AOMI) and a control group. Interventions were conducted three times per week for six weeks and pre- and post-measures of total score were collected. Results revealed that all intervention groups, with the exception of the AO and control groups, significantly improved performance following the intervention. Posthoc analyses showed that S-AOMI group improved to a significantly greater degree than the MI and AO groups, and participants in the A-AOMI group improved to a significantly greater degree than the AO group. Participants in the A-AOMI group did not improve to a significantly greater degree than the S-AOMI group (p =1.00). These findings suggest that combining AOMI, regardless of how it's combined, may be the beneficial method for improving the learning and performance of aiming skills.

Keywords: Motor skill learning; Motor imagery; Aiming; Action observation

Introduction

Motor imagery (MI) is the process of mentally rehearsing actions, typically without overt action or physical output (Jeannerod, 2001). It is well established that MI interventions can contribute to improvements in performance and learning in a wide variety of motor skills (Cumming & Williams, 2012; Wakefield, Smith, Moran, & Holmes, 2013). To explain such benefits, researchers have posited several explanations to explain improvements in performance. The psychoneuromuscular theory (Jacobson, 1931) suggest mental practice facilitates performance and the learning of a movement by causing a similar pattern of muscular activation as during movement execution, which sequentially aids subsequent movement execution. In contrast, the symbolic learning theory (Sackett, 1934) proposes that the sequence of a movement is coded through symbols. Thus, by mentally rehearsing a movement sequence through the repetition of symbolic components of the movement sequence results in an improved symbolic representation.

Neuroscientific research has also provided an indication of the mechanism by which imagery interventions contribute to such improvements in motor skill performance and learning. Specifically, there is evidence that motor imagery activates similar brain regions to those involved in motor skill planning and execution (Filimon, Nelson, Hagler, & Sereno, 2007). As such, MI practice is thought to activate and strengthen the cortical pathways involved in motor skill execution and thereby contribute to improvements in motor performance (Wakefield et al., 2013).

Like imagery, action observation (AO) interventions also offer an effective method for improving performance and learning in a variety of motor skills (Ste-Marie et al., 2012). Action observation involves the deliberate and structured observation of successful motor skill execution (Neuman & Gray, 2013). The facilitation effect of AO is thought to reflect involuntary activation of motor codes that are consistent with observed actions (bottom up mechanism; Gibson 1966). The bottom-up mechanism is referred to as influences driven by the extrinsic properties of stimuli (Baluch & Itti, 2011). Supporting this postulation is evidence that observers copy the movement kinematics (speed) exhibited by a human model which are coded through biological motion through lower level mechanisms of the AO network (AON; Wild, Poliakoff & Gowen, 2010). AO also evokes activity in the areas of the brain responsible for movement execution (Caspers, Zilles, Laird & Eickhoff, 2010).

Traditionally, MI and AO have been viewed as separate intervention techniques, with researchers often comparing the two methods against each other to establish the most effective for improving performance (e.g., Ram et al., 2007; Neumann & Gray, 2013). More recently, however, researchers have begun to investigate the effects of combining action observation and motor imagery (i.e., AOMI) by instructing participants to observe an action presented in a video whilst simultaneously focusing on imagining the physiological sensations and behavioural responses associated with the observed scenario (Scott, Taylor, Chesterton, Vogt, & Eaves, 2017; Taube, Lorch, Zeiter, & Keller, 2014; Sun et al., 2016). There is now a convincing body of evidence indicating that such AOMI interventions produce increased activity in the motor regions of the brain, compared to either AO or MI alone (see Eaves, Riach, Holmes, & Wright, 2016 for a review). As such, combined AOMI approaches may be more effective for improving motor skill performance and learning than the more traditional use of either independent AO or MI (Holmes & Wright, 2017).

Despite evidence that AOMI may produce greater activity in the motor regions of the brain than the independent use of AO or MI, to date, relatively few experiments have explored the effects of AOMI on the performance and learning of sport-related tasks. Those studies that have been conducted have shown consistently positive effects for AOMI interventions, compared to AO or MI alone, in strength (Scott et al., 2017; Wright & Smith, 2009), balance (Taube, et al., 2014) and golf putting (Smith & Holmes, 2004) tasks. However, one unexplored issue in this area is how best to combine AOMI. In a recent study, Sun et al. (2016) manipulated the structure of AOMI interventions in patients recovering from stroke by asking patients to either combine AOMI simultaneously (S-AOMI) or by alternating AO and MI components (A-AOMI). Specifically, these authors employed a 4-week AOMI intervention where one group was instructed to observe a limb movement and then subsequently asked to produce a mental image of the movement (A-AOMI) whilst the other group practiced AOMI simultaneously (S-AOMI). Results showed that larger improvements in grip strength and dexterity were observed within the effected limb in the S-AOMI group.

To explain this finding the authors outlined two possible explanation: (1) that systems shared by observation and imagery may be executed simultaneously in the S-AOMI condition which may enhance cortex excitation or (2) that the observed action may enhance the effectiveness and quality of simultaneous MI by providing learners with more direct perceptual cues for the imagination of the same movement (Grèzes & Decety, 2001). Indeed, there is some neuroscientific evidence that could support this. For example, Filimon et al. (2015) and Hardwick et al. (2017) have showed that whilst both AO and MI activate the similar areas of the brain (e.g., the premotor cortex), AO activates some areas more (e.g., inferior frontal gyrus; ventral premotor areas) than MI and MI activates other areas more strongly (e.g., angular gyrus; dorsal premotor area) than AO. Given this evidence, it is possible that S-AOMI (i.e., combining both approaches concurrently) would produce increased and more widespread, activity in the premotor cortex than A-AOMI does and this is what produces beneficial motor learning effects.

The aim of this experiment was replicate and extend these findings, from a clinical population to individuals learning an aiming skill, in an effort to explore how generalizable these effects are to other, more complex, motor skills (i.e., dart throwing) that require higher levels of coordination, are temporally constrained actions and require greater levels of accuracy. It was hypothesised that AO, MI, A-AOMI and S-AOMI practice would all produce performance improvements from pre-test to post-test, relative to a control group. The extent of the performance improvements were predicted to be greater in both combined AOMI groups, compared to the independent AO or MI intervention (Eaves, Riach, Holmes, & Wright, 2016). Finally, it was predicted that the S-AOMI group would exhibit greater performance improvements when compared to A-AOMI group (as Sun et al., 2016).

Method

Participants

Fifty university students (25 males, 25 females; *Mean age* = 23.88 *years*, *SD* =3.78) were recruited. The number of participants recruited was established to be comparable to that of previous research of a similar nature (Taube et al., 2014; Wright and Smith, 2009). All participants self -reported being right-handed using the Edinburgh Handedness Inventory (Oldfield, 1971). Participants also self-reported normal or corrected to normal vision and were novice performers who had limited darts throwing experience and had not participated in any previous MI training. The experiment was approved by the faculty ethics board at the first author's institution.

Measures

Movement Imagery Questionnaire-Revised (MIQR; Hall & Martin, 1997). The MIQ-R is an eight-item inventory that assesses an individual's ability to perform visual and kinaesthetic imagery on four movements: a knee lift, jump, arm movement and toe touch. In this study, the MIQ-R was used as a screening tool, used by previous research (Smith & Holmes, 2004; Wright & Smith, 2009) . Participants physically performed each of the requested actions a single time. Following execution of the action, participants were instructed to image the movement, using an internal visual or kinaesthetic modality. Participants then rated the ease or difficulty with which they completed the imagery on a 7-point Likert type scale ranging from 1 (*very hard to see/feel*) to 7 (*very easy to see/feel*). The validity and consistency of the MIQ-R has been demonstrated by Gregg, Hall, & Butler (2010) and has been used previously in imagery studies investigating aiming tasks (e.g., Smith, Wright, & Cantwell, 2008)

Imagery Diary

Participants were provided with an imagery diary which they could complete after each MI session by the guidelines of Goginsky and Collins (1996). Participants were instructed to record any difficulties or concerns they experienced when performing imagery during the intervention period. Furthermore, engagement with the session was measured using a frequency count of sessions completed, out of a possible eighteen. The vividness and controllability of the imagery were also rated on a 7-point Likert scale (ranging from 1 being *not at all controllable not at all vivid* / 7 being *very controllable and very vivid*). Thorough use of manipulation checks to ensure the completion of and focus of the intervention have also been employed in a number of recent studies examining the efficacy of MI on performance (e.g., Frank, Land, Popp, & Schack, 2014; Guillot, Genevois, Desliens, Saieb, & Rogowski, 2012)

The Aiming Task

Concentric circle dartboard was used to collect performance data (see Figure 1). The dartboard was positioned at the centre fixed point, 1.73cm from the floor and 2.37 cm horizontally from the throwing line, as per standard darts rules. Performance (throwing accuracy score) was measured using a similar system employed by Williams, and Cumming

(2012) measured in 10 concentric circles (2cm wide). The throws were scored in relation to where the dart landed within the 10 circles, the centre of the scoring 10 points and the outer circle scoring 1 point. Darts that landed outside the circumference of the dartboard were awarded a score of zero.

Procedure

Prior to commencing the study, all participants provided informed consent and completed the MIQ-R. All participants were randomly allocated to one of four experimental groups (n =10/ group): action observation (AO); motor imagery (MI); simultaneous imagery and observation (S-AOMI); and alternate imagery and observation (A-AOMI). Each group contained five male and five female participants. All participants were given identical brief instructions of the correct dart throwing technique that they should attempt to use when completing the experiment. For example, participants were asked to focus on the centre of the board, ensuring their dart and target were in line. They were also informed about the scoring system and were instructed to aim for the centre of the board. After five practice throws, participants completed their pre-test. This enabled the participants to experience the physical sensation associated with holding a dart and executing a dart throw. The number of practice throws were comparable to that of research of a similar target based task (Williams and Cumming, 2012).

Pre and post-tests consisted of 30 dart throws split into six blocks of five dart throws. Total score was taken as the performance measure during both pre and post-tests. Based on the recommendations of others (Wakefield & Smith, 2009; Wright, McCormick, Birks, Loporto, & Holmes, 2015) participants were instructed to perform each intervention for three times per week, for a 6-week period. As previously indicated, participants' imagery diaries also served as manipulation checks, ensuring that participants had correctly performed their imagery as well as discussing deviations from normal behaviours such as sleeping patterns and physical exertion. Any further information of issues or difficulties encountered with the following MI interventions were also noted.

Interventions

Following the pre-test, the interventions were introduced to the participants. All participants, except those in the control group and AO group, received stimulus response training (SRT; Lang, Kozak, Miller, Levin, & McLean, 1980). Based on the bio informational theory proposed by Lang et al. (1980), participants were instructed to attend to specific stimulus details of the scenario that he/she finds easy to image (e.g., specific details about the environment) and response propositions such as physiological sensations (e.g., muscle tension in their muscles), visceral events (e.g., increased heart rate) and sense organs adjustments (e.g., postural changes). It has been suggested that imagery containing response propositioning can produce more vivid imagery and consequently, improves the execution of motor skills (Williams, Cooley, & Cumming, 2013). Over the 6 weeks, participants were instructed to perform imagery in the first person perspective, with their eyes open and build the image up by including additional details and/or by making the details more vivid or life like. It is important to note however, this process was participant generated and participants were not directed to specific propositions by the researchers.

Control group

The control group watched a video interview with a professional darts player three times per week, which took the same amount of time as the videos presented to the other treatment groups. The video was a documentary about darts, but did not provide advice on the technique to aid the execution of a dart throw performance. Control participants were informed that the study was designed to investigate the perception of dart throwing amongst university students over a 6-week period. This procedure similar to the placebo used by Smith and Holmes, (2004) and Smith et al. (2008).

Action observation intervention

The AO group were provided with the short pre-recorded observational video containing six blocks of five dart throws, equalling thirty throws. Participants in this treatment group were instructed to watch one of the pre-recorded videos (female hand/male hand) equivalent to their sex. Video recordings provided participants with a view of the model's right hand and forearm from a first person perspective (see Figure 1). A first person perspective was employed for two reasons. First, there is evidence that action observation from a first person perspective produces greater activity in the motor system than when viewed from a third person perspective (Alaerts, Heremans, Swinnen, & Wenderoth, 2009). Second, this perspective provides a closer behavioural match with physical performance than would a third person perspective (Wakefield et al., 2013) and also ensured consistency with conditions involving motor imagery which utilized a first person perspective based on the PETTLEP imagery guidelines (Holmes & Collins, 2001). The video recording consisted of observing an intermediate player executing thirty throws while attempting to hit the bullseye, with a total score of 222/300. The characteristics of the model were comparable to that of previous research of a similar nature suggesting the observation of trials that contained degrees of error facilitated rapid learning of a fine motor task than observing trials that contained minimal error (LeBel, Haverstock, Cristancho, van Eimeren, & Buckingham, 2017). The observational video was recorded in the same laboratory and with the same equipment as used by participants in the study, allowing the combined intervention groups to emphasise the environment component of the PETTLEP model.

Imagery intervention group

Each participant started by generating a simple image of themselves holding a dart, with attention being drawn to aspects of the imaged scenario that they found easy to image. Additional details to the relevant scenario were then progressively added (e.g. sensory modalities, physiological sensations and emotional response). The completed script was then used by the participant to practice during each imagery session. All aspects of the PETTLEP model imagery (Holmes and Collins, 2001) were addressed in the interventions. The MI group, along with all groups that incorporated MI into the intervention (A-AOMI and S-AOMI) completed all elements of the model (see Table 1 for details of the PETTLEP intervention).

Alternate imagery and action observation (A-AOMI) group

The A-AOMI group were provided with the pre-recorded observational video containing six blocks of five dart throws, equalling 30 throws. Participants were required to observe a block of five dart throws and were then were instructed to engage in PETTLEP MI for a further five dart throws in an alternate manner until 30 throws were competed. The structure of the trials allowed the participant to become accustomed to the requirements of the intervention and were comparable to the trial structure of the study by Sun et al. (2016). The PETTLEP MI aspect of the video was regulated by real time, as the screen during this intervention showed a static dartboard and incorporated audio cues of the darts hitting the board to ensure participants were imaging with the same timing as the observational element of their intervention.

Simultaneous imagery and action observation (S-AOMI) group

The S-AOMI group were provided with the pre-recorded video containing six blocks of five dart throws, equalling 30 throws. The video content was equivalent; however, participants were given additional imagery instructions. Participants were instructed to observe the dart throws shown in the video whilst simultaneously imaging the physiological feelings and sensations that they would experience when executing performing the dart throw.

Data Analysis

The data obtained from the MIQ-R imagery ability questionnaire were analysed using separate one-way analyses of variance (ANOVAs) for the visual and kinaesthetic sub-scales to establish any differences in imagery ability prior to the start of any intervention. Dart throwing performance was measured as the mean of total throwing accuracy score (out of 300 points) for each group. This data was analysed using a 5 (group) x 2 (time) mixed between within analysis of variance (ANOVA). Significance was measured at the .05 level. Where the ANOVAs revealed significant effects, post-hoc Tukey tests were used to establish where any significant differences existed. Effect sizes were calculated using partial eta squared (η_p^2) for omnibus comparisons and Cohen's *d* for pairwise comparisons (Lakens, 2013).

Results

Self-report data

Results from the one-way ANOVAs revealed a significant difference in MIQ-K scores, $F(4, 49) = 6.225$, $p < .001$, $\eta_p^2 = .356$ and MIQ-V scores, $F(4, 49) = 9.92$, $p < .001$, $\eta_p^2 = .469$. Post-hoc Tukey tests showed that participants in the control group scored significantly lower than participants in the intervention groups (all $p < .05$) for both visual and kinaesthetic imagery ability (see Table 2). This result was expected as, prior to the pre-test, low scoring imagers were deliberately placed into the control group prior to testing to reduce the likelihood of control group participants engaging in spontaneous imagery of the task throughout the intervention period. Importantly, no significant differences between imagery ability were apparent for intervention groups on MIQ-K scores and MIQ-V scores (all p >.05).

Self-report data: manipulation checks

Inspection of the imagery diaries and manipulation checks conducted revealed that participants reported performing their imagery as instructed by the researcher. Prior to the completion of the testing, a minimum of 14 intervention sessions was set as the cut-off point, and completion of less than 14 would result in the participant's data being removed from the study. As all participants reported completing at minimum of 14 sessions, all data were included in the study. Furthermore, there were no significant imagery content differences for imaging, ease of visual or kinaesthetic imagery, or imagery vividness (p's > .05). These data are presented in Table 3.

Performance

Results revealed a significant main effect for time, $F(1, 9) = 20.37$, $p < .001$, $\eta_p^2 = .694$, and a significant main effect of group, $F(4, 36) = 3.172$, $p = 0.03$, $\eta_p^2 = .261$. There was also a significant time x group interaction, $F(4, 36) = 6.44$, $p < .001$, $\eta_p^2 = .417$. Within group post hoc comparisons using the Tukey test revealed significant improvements from pre-test to post-test in the A-AOMI (p = .001 d = 1.57), S-AOMI (p = .001, d = 1.79) and MI (p = .020, d = 1.14) groups. Participants in both the AO group and control group did not significantly improve performance from pre- to post-test. Between group post hoc tests showed that the S-AOMI group improved to a significantly greater degree than the AO (p =.03, d = 1.17), MI (p =.05, d =1.11), and control (p=.001, d = 1.74) groups. Participants in the A-AOMI group improved to a significantly greater degree than the AO (p=.05, d =0.95) and control (p =.002, d = 1.61) groups. Participants in the A-AOMI group did not improve to a significantly greater degree than the S-AOMI group (p =1.00; see Figure 2).

Discussion

The aim of this experiment was to explore the effects of differing combinations of AOMI practice against independent AO or MI practice on performance in an aiming task. The results indicate that both combinations of imagery and observation training (i.e., S-AOMI and A-AOMI) can improve target performance over-and-above AO or MI interventions alone. This corroborates the findings of previous research that has reported similar improvements in motor performance after AOMI interventions (see Eaves et al., 2016). The findings of this experiment indicate that combining imagery and observation may provide the optimal method for producing performance improvements in target throwing tasks.

Importantly, however, both S-AOMI and A-AOMI appear to provide equivalent performance enhancements during for this type of skill, which is in direct contrast to the findings of Sun et al. (2016). One possible explanations for the discrepancy could be due differences between the participants in both studies. For example, Sun et al. (2016) recruited patients recovering from stroke while our study used ‘non-affected’ adults. As patients recovering from stroke usually have impairments in working memory (WM) (Constantinidis & Klingberg, 2016) it could be the case that the S-AOMI condition reduced the demand on WM resources by eliminating the need to remember the action observed in order to guide their MI. We propose that the participants in our study, whom presumably had normal levels of WM, had sufficient WM resources to cope with the demands of either AOMI combination. Therefore the optimal structure for AOMI interventions may be an important consideration for clinical populations who have impairments in WM such as the elderly (Schott, 2012), children with developmental disorders (Alloway, 2011) or patients with Parkinson’s disease

(Lees & Smith, 1983). Future research is warranted to evaluate the merits of such AOMI combinations in these populations.

One explanation for why the two AOMI interventions resulted in greater performance improvements than the independent AO or MI interventions may relate to the manner in which they produced activity in the motor regions of the brain. Although no measure of neural activity was included in this experiment, it is well established that both AO and MI evoke activity in the motor regions of the brain (e.g., Grezes & Decety, 2001), and that AOMI interventions elicit greater activity in these brain regions than independent AO or MI (Eaves et al., 2016). As such, by engaging in both AO and MI three times per week for six weeks, either in a simultaneous or alternate manner, participants in the S-AOMI and A-AOMI groups may have experienced increased activity in motor-related brain regions during their intervention than either the independent AO or MI groups. Although the independent AO or MI interventions would likely still have elicited activity in similar regions of the motor system, this is likely to have occurred to a lesser extent than in the two AOMI groups, and this may explain why their performance did not improve to the same level as either combination groups. To substantiate this explanation, further research utilizing mobile electroencephalography technology to record cortical activity during AOMI interventions alongside performance measures would be welcome.

Another explanation for the greatest improvements being found in the two AOMI intervention groups may be that AOMI helps to develop a common motor representation that helps to prime top-down attentional processes (e.g., action intention, movement programming and preparation) which are important for task execution (Jeannerod, 2001). Evidence to support this explanation can be taken from studies that have shown similar eye-movement patterns during physical practice and MI (Heremans et al., 2009), physical practice and AO (Flanagan & Johansson, 2003) and MI and AO group (McCormick et al., 2012). This suggests that eye-movement patterns observed in motor simulation interventions may reflect the shared neural network used to plan and control visually guided actions during physical practice. Therefore, it is possible that the improvement in darts throwing performance in this study was attributable to the development of optimal eye-movement strategies important for aiming. In fact, previous research by Frank, Land and Schack (2015) has shown that mental simulation of a golf-putting task resulted in more elaborate motor representations which facilitated more optimal eye-movement behaviours (quiet-eye (QE) durations; Vickers, 2007) shown to be important in aiming skills. Future research should therefore explore the utility of AOMI interventions for implicitly facilitating QE aiming durations in such tasks.

Our data showed no significant change in performance in the AO group, yet significant improvements in the MI group. This is surprising, as previous studies that have employed AO in isolation have showed this to be effective (e.g., Battaglia et al., 2014; Gatti et al., 2013). One potential explanation for this finding may be that MI is more cognitively demanding compared to AO. For example, MI depends on the individual’s ability to rehearse or recruit the relevant motor representation and to perform the action covertly while generating visual and kinaesthetic imagery. On the other hand, AO interventions provide a model of the action with minimal instruction and therefore imposes a lower cognitive demand. This disparity in the mental resources employed during either intervention in isolation may explain these differing effects on performance and learning.

A potential limitation of the study is our decision to place poor imagers into the control group. However, this decision was taken to reduce the likelihood of spontaneous imagery throughout the intervention period that has been suggested in similar research (i.e., Smith et al., 2008). Despite this justification, this decision will have an impact on how generalizable these findings maybe be individuals with poor imagery ability. Another limitation of our study relates to the nature of the performance measurement used. Criticism of this method suggests that it lacks sensitivity and is inappropriate for the capture of the true characteristics of performance such as direction and variability around the target (see Fischman, 2015). Finally, the decision to ask participants to complete the intervention at home may be a further limitation of the study design, as we cannot ensure subjects integrity to engage in the intervention period. However, the improvements in performance suggest that this was not the case.

In conclusion, in this study we have shown that two types of AOMI interventions improved dart throwing performance over-and-above AO or MI interventions alone. This offers further behavioural evidence to support the efficacy of AOMI for improving performance in sport. As such, sport psychologists should consider adapting their practice to include the delivery of combined AOMI interventions. Finally, further research should seek to explore whether the two combinations AOMI provide similar benefits when employed in other populations and with other, more complex motor skills.

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Conflict of interest

None.

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Figure Captions

Figure 1. An example still shot from the Action Observation video

Figure 2. Mean (± s.e.m) pre and post-test throwing accuracy scores for each experimental group (*$p < .05$, **$p < .001$).

Figure 1

Figure 2

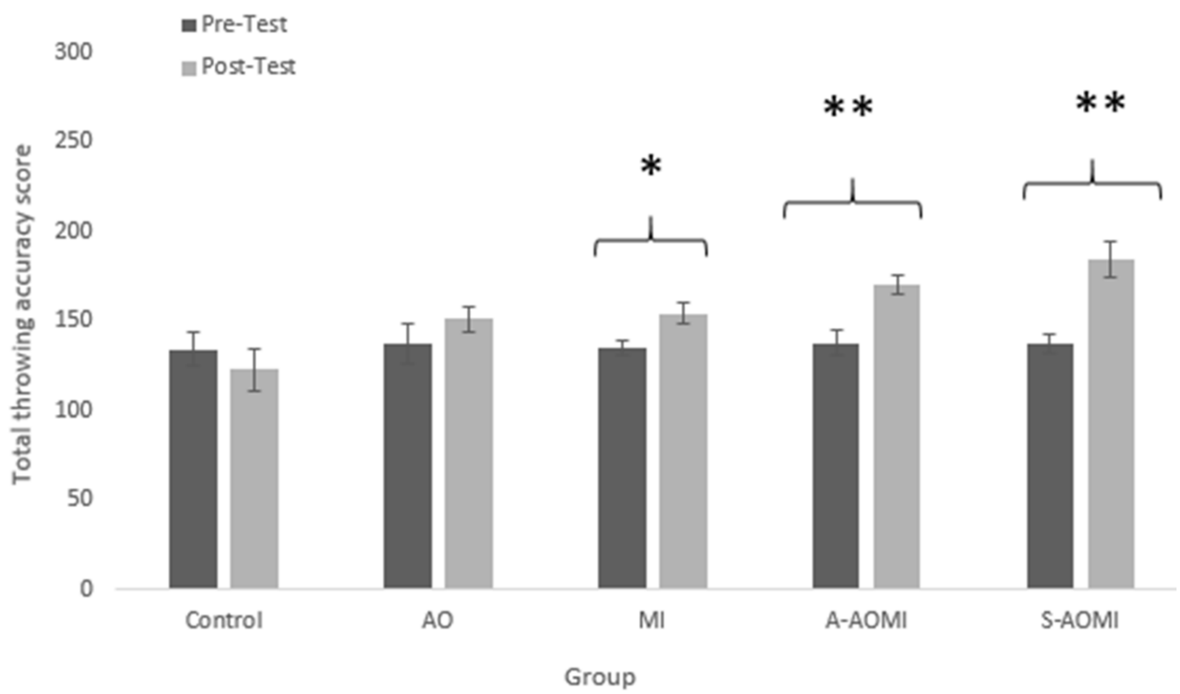
Pre-Test
Post-Test
Total throwing accuracy score
300
250
200
150
100
50
0
*
**
**
Control
AO
MI
A-AOMI
S-AOMI
Group

Table 1. Summary of the PETLEP motor imagery content for all imagery instructions

PETTLEP category	Description
Physical	Participants were instructed to stand while holding a cylindrical object similar to a dart or pen suggested by Holmes and Collins (2001). Participants were also instructed to adopt the stance recognised in dart throwing performance.
Environment	PETTLEP MI was performed at home. Participants were instructed to watch the video static dartboard within the video from their pre-test
Task	Participants performed a series of dart throws to emulate the performance measure as closely as possible. This included the intricacies associated with their specific skill level on the task.
Timing	Participants were instructed to perform MI in ‘real time’, rather than in slow motion or faster than normal. Auditory cues. For example, audio feedback of the darts making contact with the board during pre-test conditions.
Learning	Participant were instructed to revisit their imagery scripts after every two week period of the intervention and make any necessary adaptations depending on their perceived development of the skill.
Emotion	Scripts were created after the pre-test allowing familiarisation with the dart throwing action. This was based on the results of the stimulus and response training (Lang et al., 1980) that had been undertaken. Participants often identified associations with the physical sensations or of dart throwing.
Perspective	Participants were instructed to image in the first person perspective in order to best reflect the perspective from physical completion of the task.

Table 2. Mean MIQ-R scores and (SD) for each experimental group.

Group	MIQ-R Visual	MIQ-R Kinaesthetic
A-AOMI	6.7 (0.64)	5.9 (0.98)
S-AOMI	6.4 (0.52)	6.2 (0.64)
MI	6.3 (0.66)	6.3 (0.93)
AO	6.0 (0.62)	5.8 (0.61)
Control	4.8 (0.81)	4.5 (0.61)

Table 3. Manipulation check mean scores (SD) for number of sessions completed, ease of visual, kinaesthetic imagery, and imagery vividness for each experimental group.

	A-AOMI	S-AOMI	MI
Frequency of imaging	16.1 (0.54)	16.4 (0.47)	15.8 (0.53)
Ease of imagery (see)	6.7 (0.15)	6.5 (0.17)	6.7 (0.15)
Ease of imagery (feel)	6.5 (0.16)	6.5 (0.18)	6.7 (0.15)
Vividness of imagery	6.5 (0.16)	6.5 (0.16)	6.7(0.15)