Self-modelled versus skilled-peer modelled AO+MI effects on skilled sensorimotor performance

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Abstract

Action observation (AO) and motor imagery (MI) are simulation states that have been demonstrated to independently enhance motor skill performance. Historically, AO and MI were examined in isolation from one another; however recent neurophysiological and behavioural evidence indicates that using MI *during* AO (AO+MI) may be more potent at enhancing performance than either simulation state alone. The AO component of AO+MI is typically delivered via a self-modelled or peer-skilled model paradigm, via an observation video. The purpose of the proposed study is to further examine the implementation of AO+MI states by directly comparing the effectiveness of self-modelled AO+MI with peer-skilled modelled AO+MI to augment performance on a golf putting task with a sample of 56 skilled golfers. Our primary hypothesis predicts that skilled participants who engage with a self-modelled intervention will improve their performance more than those engaging with a peer-skilled model intervention. This hypothesis is predicated on the idea that self-modelling will be used in the context of performers' existing mental representation and will facilitate improved performance, whereas the peer modelling may destabilise skilled performers' existing mental representation.

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Introduction

Motor imagery (MI) and Action Observation (AO) are simulation states that have been demonstrated to activate similar neural mechanisms within the motor system as physical execution (Jeannerod, 2001). Previous research has routinely examined MI and AO as separate paradigms with their independent implementation demonstrating consistent positive effects on motor skill performance (Driskell, Copper, & Moran, 1994; Ashford, Bennett, & Davids, 2006). The combined application of AO+MI has emerged as a new paradigm within simulation state research (Vogt, Di Rienzo, Collet, Collins, & Guillot, 2013; Eaves, Riach, Holmes, & Wright, 2016), with promising behavioural and neurophysiological effects being demonstrated across a number of motor tasks including dart throwing (Romano-Smith, Wood, Wright, & Wakefield, 2018; Romano-Smith, Wood, Coyles, Roberts, & Wakefield, 2019), golf putting (Smith & Holmes, 2004; Frank, Land, & Schack, 2013; McNeill, Ramsbottom, Toth, & Campbell, 2020), basketball free throwing (Wright, Woods, Eaves, Bruton, Frank, & Franklin, 2018), hamstring curl strength (Scott, Taylor, Chesterton, Vogt, & Eaves, 2018), and novel motor skills (Gatti et al., 2013).

Neurophysiological research demonstrates that AO+MI appears to illicit significantly more cortico-motor activity compared to AO or MI independently. For example, Taube et al. (2015) reported that when using a simulated balancing task during functional magnetic resonance imaging (fMRI), AO, MI, and AO+MI all have unique neural signatures. Specifically, AO+MI evoked greater activity in the supplementary motor area, basal ganglia, and cerebellum when compared to AO alone and greater bilateral activity in the cerebellum compared to MI. Villiger et al. (2013) have also used fMRI to report key differences in the neural activity associated with AO and AO+MI. During a foot movement task, AO+MI enhanced activation of the motor network and regions responsible for attention and goal-directed movement (Inferior parietal lobule, ventral Premotor Cortex regions and the putamen specifically). Further to this, Nedelko, Hassa, Hamzei, Schoenfeld, and Dettmers (2012) studied brain activation during AO and AO+MI of simple, object-related hand actions, and reported greater cortical activation in both cerebellar hemispheres, caudate nucleus, ventral and dorsal premotor cortex, inferior parietal cortex, and the supplementary motor area associated with an AO+MI condition when compared to an AO condition. Other research suggests that the combination of AO+MI may facilitate corticospinal excitability to a significantly greater extent than either AO or MI independently (see Wright et al., 2018; Wright, Williams & Holmes, 2014). At this juncture, there is sufficient neurophysiological evidence to suggest that AO+MI may be a more effective method of motor simulation than AO or MI alone, with behavioural evidence emerging in support of AO+MI's use.

In addition to the neurophysiological evidence for the added benefits of combining AO and MI, behavioural research has shown AO+MI to be superiorly beneficial for a number of simple and complex motor tasks. In one of the earliest studies using AO+MI, Smith and Holmes (2004) demonstrated that AO+MI was significantly more effective than MI alone for enhancing performance in a golf putting task. Recently, Romano-Smith and colleagues have demonstrated in two separate studies that AO+MI interventions significantly improved performance in a dart throwing task compared to control, AO alone, and MI alone groups (Romano-Smith et al., 2018; Romano-Smith et al., 2019).

Evidence for the effectiveness of AO+MI in comparison to MI or AO alone has also been demonstrated in strength-based skills. For example, Scott et al. (2018) demonstrated this effect utilising an eccentric hamstring curl task in which hamstring strength (peak hamstring torque) only increased significantly following an AO+MI intervention but not in either of two pure MI groups where participants imagined either the hamstring curl task or an unconnected upper limb control task. In addition, Wright and Smith (2009) demonstrated that participants in a PETTLEP imagery group who concurrently watched a video improved significantly more from baseline to post intervention than those in a traditional imagery group on a bicep curl task. Overall, there is a growing body of research suggesting that AO+MI can further augment motor performance and elicit greater activity in motor related cortical regions than AO or MI alone. AO+MI has also recently been demonstrated to be effective at enhancing movement kinematics by Romano-Smith et al. (2019) who suggested that a significant decrease in angular peak velocity, which was only present in the AO+MI conditions was associated with an increase in accuracy and decrease of errors in the throwing task. With this in mind, it is important to consider different methods for implementing AO+MI interventions for optimal effectiveness.

In order to understand the optimal implementation of AO+MI interventions, it is necessary to examine the existing AO research in order to inform AO+MI implementation and design going forward. Typically, AO is implemented via one of two paradigms, self (Clark & Ste-Marie, 2007; Zetou, Kourtesis, Getsiou, Michalopoulou, & Komotini, 2008; Law & Ste-Marie, 2005) or peer-skilled modelled (Romano-Smith et al., 2018; Romano-Smith et al., 2019) observational modelling. The self-modelled paradigm involves performers observing themselves performing the desired action on video. This method has been demonstrated to improve self-assessment, improve technical execution, and increase self-efficacy (Ste-Marie et al., 2012). Alternatively, the skilled-modelled paradigm involves a participant observing a highly skilled actor performing the optimal characteristics of the chosen motor skill on video, thereby offering the participant the opportunity to learn the most desirable method of performance (Pollock & Lee, 1992). Despite the longevity of AO research interest; there has been a relative lack of work *explicitly* examining the differences between self-modelled and skilled-modelled paradigms, with mixed findings in the few studies that do. For example, Pollock and Lee (1992) showed no significant difference between self and skilled modelling in a video game task with a novice sample, while Clark and Ste-Marie (2007) have suggested that self-modelling may be more effective than other model types for learning swimming skills. An important consideration may be the *type* of skill engaged in, a recent review by McNeill, Toth, Harrison, and Campbell (2019) suggested that skill type may moderate the effectiveness of motor simulation interventions. In addition, meta-analytic results from Ashford et al. (2006) suggest that AO may be most effective for serial and continuous skills.

Finally, an issue we feel pertinent to moving this area forward relates to the question of optimal implementation of AO+MI and how we should consider the expertise of the individual performing the AO+MI. To date, this question has not been addressed. Vogt et al. (2013) highlight three different potential types of AO+MI. Firstly, congruent AO+MI where performers observe and imagine the exact same task. Secondly coordinative AO+MI where performers observe one task and imagine performing a similar, related task and finally, conflicting AO+MI where the imagined and the observed actions oppose one another. An example of coordinative AO+MI could be one where a skilled performer engages with a peer skilled model AO+MI intervention for a skill with which they are already proficient. In this scenario, the representation of the task as executed by the skilled model may differ from that of the performer, and destabilize an existing, functional mental representation of the skill, leading to poorer performance following engagement with the AO+MI intervention. The same performer engaging with a self-modelled AO+MI intervention could be considered an example of congruent AO+MI.

The current study makes a novel, direct comparison between the effects of congruent AO+MI and coordinative AO+MI on performance in a skilled sample. There is recent precedent for making this comparison, Bruton, Holmes, Eaves, Franklin, and Wright (2020) demonstrated that coordinative AO+MI resulted in competition between the observed and imagined action, resulting in the switching of visual attention between observed and imagined stimuli in a finger abduction task. In contrast, participants in a congruent AO+MI group focused their visual attention directly at the index finger which was the task relevant stimuli displayed to them. Despite this recent evidence highlighting differences between implementations of AO+MI interventions, there is a dearth of research directly comparing how self-modelled paradigms versus peer-skilled models augment subsequent performance on sensorimotor tasks.

The purpose of the current study is to examine whether engaging in self-modelled AO+MI (SMAO+MI) or skilled peer modelled AO+MI (SPAO+MI) more greatly enhances sensorimotor skill performance in already skilled performers. Golf putting is an exemplar, self-paced motor skill which has been successfully used previously in the motor simulation literature (e.g., Frank et al., 2013; Smith & Holmes, 2004). Our hypotheses are as follows;

H1. Skilled participants who engage with a SMAO+MI intervention will improve their post-performance (smaller Mean Radial Error and Bivariate Error) more than those engaging with a SPAO+MI intervention. Our rationale for this hypothesis is predicated on the idea that SMAO+MI will be used in the context of performers' existing mental representation and will thus facilitate improved performance, whereas the SPAO+MI will potentially destabilize skilled performers' existing mental representation and result in competing attentional resources during the intervention.

H2. Participants who engage with SMAO+MI will also improve their overall putting consistency, as measured by SAM Puttlab (detailed description of the device provided in the methods section below) more than those who engage with a SPAO+MI intervention. The SAM Puttlab is a three-dimensional ultrasound camera system which calculates overall consistency by comparing the performers raw data values for each putt on 27 kinematic variables to a distribution of values collected from European tour professional golfers, the consistency rating is delivered as a percentage.

H3. Participants in the SMAO+MI group will improve their post-performance on key putting stroke kinematics more than those engaged with the SPAO+MI intervention. Improvements in post-performance will be manifested in kinematic metrics; Aim, Club Face Angle, Club Path and Ball Direction that approach zero degrees (optimal alignment relative to the target).

Methods

Participants

56 right-handed male golfers with a minimum of 3 years golfing experience will be included as participants in this study. An a priori power analysis was conducted using G*Power3 (Faul, Erdfelder, Lang, & Buchner, 2007) to test the difference between two independent groups using a large effect size (*f*=.4) and an alpha of .05. Results of the power analysis showed that a total sample of 52 participants with two equal sized groups of *n*=26 is required to achieve a power of .80, however to ensure the sample is appropriately powered 56 participants split into two equal groups of *n*=28 will be collected. Participants will be assigned to one of two experimental groups SMAO+MI or a SPAO+MI. In order to maintain homogeneity between the groups, participants will be assigned to their designated experimental group based on putting ability. Putting ability will be measured using an overall consistency rating provided by a SAM Puttlab device (we provide a description of the device in the following section). The logic of assigning participants on this basis is to try to ensure that there are no significant differences in skill level between both experimental groups.

SAM PuttLab

A three-dimensional ultrasound camera system will be used to record putter kinematics during the putting task (SAM PuttLab, Science & Motion GmbH, Mainz, Germany, www.scienceandmotion.de). The system will be set up 50 cm from the initial ball location for each putt and perpendicular to the target line (see Figure 1). Dedicated SAM PuttWare Pro software will be used to record the 3D position of a sensor attached and calibrated to a putter at 210 Hz with a precision of approximately 0.1mm (Karlsen, Smith, & Nilsson, 2008; Malhotra, Poolton, Wilson, Omuro, & Masters, 2015).

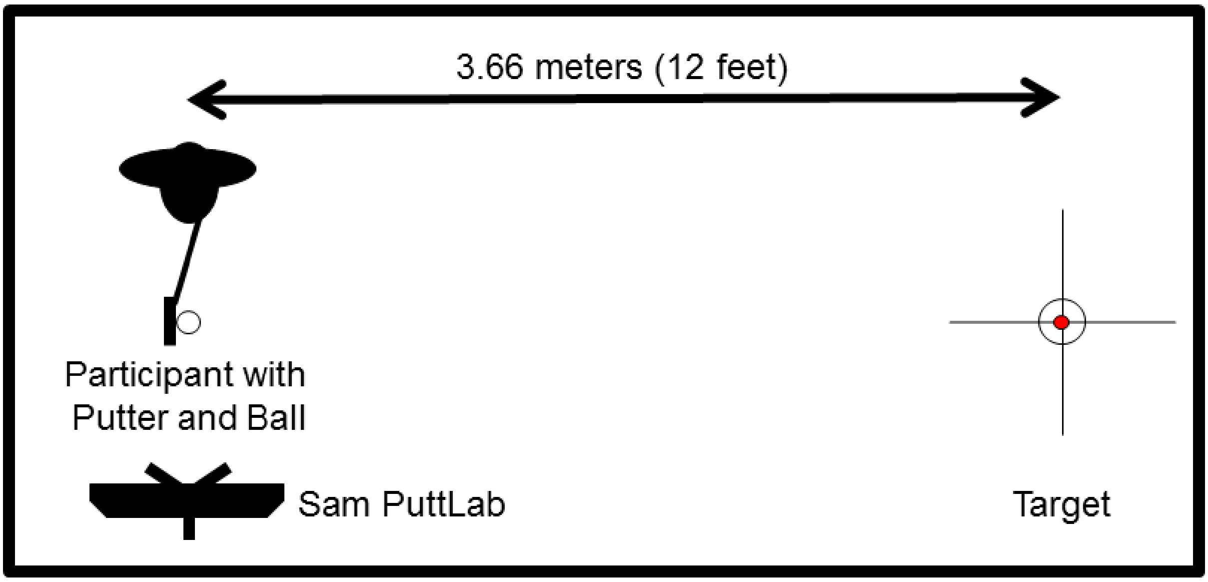

Figure 1. Proposed experimental set-up including positions of the participant, golf ball, target, and SAM Puttlab.

Procedure

Participants will be recruited from local golf clubs, and will begin by completing the Vividness of Movement Imagery Questionnaire 2 (VMIQ-2) (Roberts, Callow, Hardy, Maarkland, & Bringer, 2008). The VMIQ-2 is a 12 item questionnaire which assesses the vividness of an individual’s imagery for a variety of movements. Participants are required to image each movement from three different perspectives; internal visual imagery (IVI), external visual imagery (EVI), and kinaesthetic imagery (KI) and rate the vividness for each image on a five point Likert scale where 1 is ‘perfectly clear and vivid’ and 5 is ‘no image at all’. The VMIQ-2 has been demonstrated to have acceptable factorial, construct, and concurrent validity (Roberts et al. 2008) and has been used extensively in experimental research (Williams et al. 2012; Callow, Roberts, Hardy, Jiang, & Edwards, 2013; Lawrence, Callow, & Roberts, 2013; Wright, Williams, & Holmes, 2014) as a self-report measure of imagery ability since its conception.

After completing the VMIQ-2 a triplet with three 70-Hz ultrasound transmitters will be attached to each participant’s putter in preparation for kinematic tracking using SAM Puttlab. Each participant will complete a total of 10 practice putts on the testing area to familiarise themselves with the speed of the flat synthetic putting surface. The SAM Puttlab triplet will then be calibrated for each participant. The calibration procedure calibrates the face and lie angle of the putter to be 0 degrees when pointing directly in line with an intended target (see Figure 1). The target will be marked on the putting surface with a circular target (3.2cm in diameter) directly in the middle of a chalk outline of a golf hole (10.8cm in diameter) exactly 3.66m (12 feet) away from the start position. The chalk outline is necessary to allow for the measurement of distance error in millimetres and also to prevent potential inaccuracies in data recording that could be associated with putts deflecting off the peripheries of an actual golf hole. To ensure the putter face will be pointed directly at the target, a laser will be attached during calibration such that its beam emanates perpendicular to it and aligns onto an object placed on the target.

Participants will then complete 20 putts with instructions to ‘make the ball stop on the target’. These 20 putts will represent Blocks 1 and 2 (10 putts in each block) and combined will make up the baseline test. All participants will have their 20 putts at baseline recorded from a third person perspective down the target line (see Figure 2) using a high speed HD video camera. This recording will act as the basis for the SMAO+MI intervention (outlined in detail in the next section). After the baseline test participants will be assigned to one of the two experimental groups. Once assigned a group, participants will complete the SMAO+MI or the SPAO+MI intervention. The intervention will last approximately 10 minutes. Recently published research (McNeill et al., 2019) has demonstrated that brief exposures to AO+MI interventions can result in performance benefits in a golf putting task. The AO+MI conditions will be behaviourally matched with the physical trials (20 observed putts) and participants will repeat this twice (40 observational trials in total). Once the intervention has been completed participants will complete blocks 3 and 4 (10 putts in each block) as the post test. Previous research such as Frank, Land, and Schack (2016) has also used 40 putting trials (20 putts at baseline, 20 putts post-intervention) to quantify performance. The synthetic grass putting area is 7.2 metres X 2 metres (length X width), and is located in an indoor biomechanics research lab (see Figure 2). Any putt that exceeds the boundary of the testing area will be assigned a maximum score of 1540mm for each axis. Upon finishing block 4, participants will complete a manipulation check containing 4 Likert type questions in order to assess their imagery use and ease of interaction during the intervention (See appendix).

Figure 2. Still image highlighting the experimental environment and sample perspective of action observation video

Intervention groups

SMAO+MI

The SMAO+MI intervention will require participants to watch themselves completing their twenty baseline putts via a video recording while imagining what it *feels* like to successfully perform a golf putt. The video will be recorded from a third person and immediately behind the participant on the line of the target such that the participant has the capacity to view their entire body, the putter, and the finishing position of the ball. The instruction to participants will be '*Please watch the video as attentively as you can, while simultaneously imagining what it feels like to swing the putter rolling the ball towards, and onto the target*'. Participants will repeat this process twice, completing 40 observational trials in total. During this time, participants will be allowed to hold and swing their putter as practice putting strokes without striking a ball, allowing them to do so may enhance the vividness of the KI that they use during the intervention. Headphones will be provided to eliminate any external auditory distractions.

SPAO+MI

The SPAO+MI intervention will mimic the same protocol as the SMAO+MI group but will instead use an expert golfer as the model within the observational video. The SPAO+MI video will be recorded in the same environment as the SMAI+MI videos, ensuring that the observational content is identical in both groups, apart from the model used. The expert golfer is a former European tour professional and demonstrates exemplary putting technique with an overall accuracy rating of 86.9% and an overall consistency rating of 90.9% on SAM Puttlab kinematics. Participants in this group will receive the same instruction as in the SMAO+MI experimental group.

Measures

After each putt, the ball's final horizontal (x) and vertical (y) distance from the target will be measured. These co-ordinates will be used to calculate the overall accuracy and precision of each participant's performance across either the 20 putts prior to, or 20 putts post, the intervention. Accuracy will be assessed by calculating the Mean Radial Error (MRE) of the balls from the target. MRE is determined as the mean distance that a group of 20 putts finished from the target in mm according to equation 1

$$MRE = (\frac{1}{20}) \sum_{i}^{20} [(x^2 + y^2)^{1/2}. \tag{1}$$

Consistency will be assessed by calculating the bivariate error of the 20 putts before or after the intervention. The bivariate error is defined as the square root of a participant's 20 shots' mean squared distance from their centroids in mm according to equation 2.

$$BVE = \{(\frac{1}{20}) \sum_{i}^{20} [(x_i - x_\mu)^2 + (y_i - y_\mu)^2]\}^{1/2} \quad (2)$$

Both MRE and BVE are typical accuracy and consistency measures that have been previously used to evaluate target-based performance (Frank, Land, & Schack, 2013; Frank, Land, & Schack, 2016; Hancock, Butler, & Fischman, 1995). SAM PuttLab will be additionally used to record club face angle at address (Aim), club face angle at impact, club path, ball direction, and overall putting kinematics consistency. SAM PuttLab produces mean and standard deviation values for each block of ten putts for each metric. As such, we will pool the data in Blocks 1 and 2 (Baseline 20 putts) and Blocks 3 and 4 (Post Intervention 20 putts) to generate overall baseline and post-test scores by averaging mean values and pooling standard deviations according to equation 3.

$$SD_{pooled} = \sqrt{\frac{(SD_1^2 + SD_2^2)}{2}} \quad (3)$$

Data Analysis

Statistical analyses will be conducted using IBM SPSS software (version 25). A Shapiro-Wilkes test for normality will be conducted to examine whether the data is normally distributed. In the case of data that is not normally distributed outliers will be removed. In this case outliers would refer to the data point(s) associated with individual putts, with any putt that finishes more than three standard deviations from the mean removed. Following this, a one way analysis of covariance (ANCOVA) will be performed for each dependent variable (MRE, BVE, Aim, club face angle at impact, club path, ball direction, and overall putting kinematics consistency) to determine if post-test putting performance differed between the SMAO+MI and SPAO+MI groups while controlling for baseline scores. Vickers and Altman (2001) suggest the use of ANCOVA as a superior statistical test when comparing differences in performance change between groups because it accounts for and controls potential differences in baseline performance between groups. Significance will be measured at the ≤ 0.05 level and partial eta squared effect sizes will be calculated to quantify the magnitude of the observed effects. All data will be stored on a secure, password locked laptop computer.

Timeline

This research is expected to be completed within 6 months of stage 1 in principle acceptance.

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