Motor Imagery and Performance: The Role of Movement and Perspective

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Motor Imagery and Performance: The Role of Movement and Perspective

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Introduction

The topic of imagery has been extensively studied since the early days of psychology. From the early introspective studies of Sir Francis Galton to the brain-scanning studies of today, the thought modality involving quasi-perceptual images has always fascinated researchers in various fields of psychology. Without doubt, one of these fields is sport psychology (Gregg, Hall, & Nederhof, 2005). From skill acquisition to performance enhancement, from motivational purposes to injury rehabilitation, mental imagery has been studied and applied in numerous aspects of sport and exercise activity. Although the term "imagery" evokes the realm of visual perception, it includes all quasi-perceptual states. That being said, the vast majority of philosophical investigation and psychological research on imagery has focused on visual images (Tye, 1991). Within the field of sport psychology, visual imagery research accompanies research on kinesthetic and movement imagery. Kinesthetic imagery refers to the quasi-perceptual experience of muscle and joint movement, whereas movement imagery involves that of an imaginative, multi-perceptual experience of body movement or motion of an external object. The combination of visual (VI), kinesthetic (KI), and movement imagery is commonly considered under the label of motor imagery (MI), and this kind of imagery is the focus of imagery research in sport psychology. This focus has increased immensely in the last three decades. A recent literature review of MI research has found more than 20,000 publications on the topic, compared to only 122 found in a literature review in 1980 (Schuster et al., 2011).

Early Theories of Mental Practice

Early imagery research in sport psychology was characterized by efforts in understanding the components of Mental Practice (MP) adopted by successful athletes (Morris, Spittle, & Watt, 2005). MP is generally defined as the rehearsal of a physical task without observable movement (Hecker & Kaczor, 1988). The goal of MP is to aid the acquisition of new physical skills or the improvement of existing ones. Two main theories emerged from these studies.

Psychoneuromuscular theory. One of the first explanations for the effectiveness of MP involved the conception of micro-muscular activity during the process of imagining a certain movement. In a series of 1930s studies, Edmund Jacobson found specific muscular activity in participants who were imagining standard movements, such as a bicep curl, although substantially smaller in magnitude compared to the actual movement (as cited in Morris et al., 2005). Alternative explanations to the psychoneuromuscular theory include anticipation of actual movement, muscular specificity of the imagined movements, and task-specific rather than movement-specific activation. A recent study by Slade, Landers, and Martin (2002) addressed most of these criticisms by monitoring participants' electro-muscular activity of bicep and tricep muscles during an imagined one-arm dumbbell curl. Although more activity was found within the active arm during imagery than in the passive arm (or in a control condition without imagery), electro-muscular activation was different in amplitude and pattern compared to that of participants who physically performed the dumbbell curl (Slade et al., 2002).

Another line of research that contrasts the psychoneuromuscular theory focuses on the cognitive aspects of MP. A meta-analysis of an extensive amount of research on MP by Driskell, Copper, and Moran (1994) concluded that tasks which require more cognitive skills than physical abilities benefited more from MP.

Symbolic learning theory. While Jacobson's psychoneuromuscular theory was gaining support, Sackett was developing a diametrically opposite approach (as cited in Morris et al., 2005). His symbolic learning theory claimed that the function of MP is to strengthen the neural pathways involved with more abstract aspects of a skill such as timing, sequence, and planning (as cited in Morris et al., 2005). Consequently, the more cognitive a skill is, the more it should benefit from MP. Moreover, since the acquisition of a new skill involves the understanding, planning, and timing of a sequence of movements, novices should benefit more from MP than experts. Ryan and Simons (1981) found support for the first claim by analyzing the differences between two tasks remarkably distant on a cognitive-muscular continuum. These tasks were standing on a balance board and navigating a labyrinth using an apparatus similar to an Etch-A-Sketch (Ryan & Simons, 1981). Performance in the balance board task did not benefit from MP when compared to a non-practice group, but a significant difference was found between MP and non-practice in the labyrinth task (Ryan & Simons, 1981). An investigation by Ziegler (1987) using a foul-shooting basketball task found that novice players benefited more from MP than novice players with traditional physical practice. However, it should be noted that Driskell et al. (1994) did not find significant differences in performance gains between novices and experts in their meta-analysis on MP studies. In support of the symbolic learning theory, Wuyam et al. (1995) found that experienced athletes showed significantly higher ventilatory responses when imaging running on a treadmill as opposed to imaging letters, while this difference was not found in non-experienced athletes. Finally, it also appears that primarily physical tasks can benefit from MP, although the gains are less than on mainly cognitive tasks (Driskell et al., 1994).

As Morris et al. (2005) point out, the ambiguities of psychoneuromuscular theory and symbolic learning theory might have emerged from their research approach. That is, the focus was in explaining why MP was effective rather than enhancing an understanding of what MP really entailed.

Cognitive Theories of Imagery

Studies such as Ryan and Simons' labyrinth task (1981) shifted the focus of imagery research from largely physical skills to largely cognitive skills. Imagery research in cognitive psychology started to analyze its subject matter through the lenses of information processing. That is, do we store motor images in a step-by-step or parallel fashion? For instance, one can conceive downhill slalom skiing as a sequence of turns or as movements and anticipation for the next gate happening at the same time.

Dual-code theory. Paivio (1975) claimed that imagery has strong influence on learning because images are stored both visually and verbally. When we form an image of a shooting target, we not only store such an image visually, but also verbally as, say, "skeet." The advantage of this dual coding is that one can retrieve the memory of the event from either code (Morris et al., 2005). Additionally, Paivio (1975) demonstrated that these two coding processes are independent, meaning that forgetting in one realm is independent of forgetting in the other. One of the limits of this theory is that it looks only at associative learning. However, this does not seem to be a strong limitation as the vast majority of sport skills are dominated by associative learning processes (Morris et al., 2005). A more relevant criticism points at the fact that Paivio discusses only visual images, which is only one of the many possible kinds of imagery, and only part of what athletes report their imagining content to be (Morris et al., 2005).

Bioinformational theory. The theories above exposed conceptualized images as "raw" or incomplete versions of actual percepts or movements. Pylyshyn (1992) proposed a different conceptualization of imagery as a non-perceptual phenomenon defined by propositional codes. Propositions are defined as the smallest units for which a true-or-false judgment can be made (Pylyshyn, 1992). Lang's bioinformational theory rests on the propositional view of images, and distinguishes between stimulus and response propositions (as cited in Morris et al., 2005). Stimulus propositions describe the specific features of stimuli, such as "a soft-grip tennis racket." Response propositions describe specific response patterns, such as "contraction of pectoral muscle and twist of the torso." Lang's theory claims that learning occurs when these two kinds of propositions are linked, and the way in which imagery aids performance is through the strengthening of these links (as cited in Morris et al., 2005). Morris et al. (2005) report several studies supporting Lang's claim that response propositions elicit more physiological responses. However, the majority of these studies are not within the scope of sport psychology research. This should not come as a surprise since Lang developed his theory to understand the role of imagery in treating phobias and anxiety disorders (as cited in Morris et al., 2005). Recently, Smith, Holmes, Whitemore, Collins, and Devonport (2001) conducted a sport psychology study that provides support for Lang's claims. They had participants go through imagery training that involved either stimulus-only or response-only scripts, and found that the response group performed better than the stimulus group, which, in turn, performed better than a control group with no imagery training (Smith et al., 2001). However, it should be noted that other studies did not find this difference in performance. For instance, Ziegler (1987) did not find significantly different performance improvements between free-shooters who were trained with stimulus-only imagery scripts and free-shooters who were trained with scripts rich in stimulus and response instructions. If Lang's claim that imagery strengthens stimulus and response propositions is correct, then Ziegler's stimulus-response group should have improved more than the stimulus-only group.

Ahsen's triple-code theory. One aspect of imagery that should be considered is the different meaning that a certain image can have among individuals. Although Lang's bioinformational theory mentions the importance of meaning propositions, Ahsen's triple-code theory stresses the fundamental role of meaning in the efficacy of imagery (as cited in Morris et al., 2005). For instance, imagining playing the final tennis match at Roland Garros will have a completely different emotional meaning for the 2013 champion, Nadal, and the 2013 runner up, Ferrer. Also, imagining the same skill can be used for different purposes. Recalling the tennis example, one can either imagine strictly the technical aspects of serving or imagine a successful serve and the crowd cheering. Both of these images will aid performance, but in different ways, namely technical improvement and enhanced confidence. An indirect consequence of Ahsen's stress on meaning is that positive imagery–whether aimed at gains in confidence or technique–will lead to better performance than negative imagery. A recent study by Cumming, Nordin, Horton, and Reynolds (2006) investigated the different effects on performance for groups trained with either facilitative or debilitative imagery scripts in a dart-throwing task. What determined the positivity or negativity of the script was mainly the imagined performance; leading the dart either in the bullseye or outside of the board. Results showed that participants in the facilitative group enhanced pretest performance whereas those in the debilitative group actually performed worse (Cumming et al., 2006).

Psychological State Explanations

Alongside the cognitive theories of imagery that have been developed to explain performance enhancement in sports, researchers have also focused on different explanations concerned with psychological states such as arousal, anxiety, confidence, and motivation. The rationale behind this comes from studies such as Cumming et al. (2006) in which the difference in imagery is not about processing techniques but about motivation and reaction to outcomes.

Paivio's imagery types. In an attempt to create a framework comprehending the cognitive and psychological aspects of imagery, Paivio (1985) developed a model that distinguishes between cognitive and motivational imagery, and between specific and general imagery. The interaction of these components leads to four kinds of imagery with their specific functions. The aim of Cognitive Specific (CS) imagery is the improvement of a specific motor skill (Paivio, 1985). The vast majority of experiments inspired by the cognitive theories discussed above involved CS imagery interventions, such as the perspective of imagery or the presence of actual movement during imagery. Cognitive General (CG) imagery involves playing strategies and feelings of movement wholeness similar to those a golfer employs on the teeing ground. One of the challenges of CG imagery research is the reproduction of the play strategy in a controlled, experimental setting. The problem is evident in the literature, with research relying mainly on case studies and self-reports (Hall, Mack, Paivio, & Hausenblas, 1998; Guillot & Collet, 2008). Motivational Specific (MS) imagery involves specific behavioral situations of success, such as standing on a podium after a victory or receiving a round of applause after a performance. Additionally, elements of intrinsic motivation have been associated with MS imagery interventions (Evans, Jones, & Mullen, 2004, as cited in Guillot & Collet, 2008). This finding is particularly interesting since intrinsic motivation is one of the main features of *flow*, the particular state of mind–often reported by successful athletes–of full and total immersion in an activity (Jackson & Czikszentmihalyi, 1999). Finally, motivational general imagery is further divided into Arousal (MG-A) and Mastery (MG-M) and involves primarily competitive scenarios. The first one deals with stress levels and relaxation techniques, whereas the second deals with feelings of mastery in the competitive settings, including mental toughness and confidence (Hall et al., 1998).

Functional Equivalence and Neuropsychological Explanations

The development of new brain scanning technologies such as EEG, PET, and fMRI has allowed a deeper understanding of the relationship between imagery and percepts. At first, a great deal of research in neuropsychology involved comparing the neural activity of visual imagery and visual perception. Kosslyn et al. (1993) used PET scans to see the similarity in brain activity between visual imagery and perception. In a series of experiments in which participants imagined individual letters on a squared grid, participants' brain activity was remarkably similar to that observed when the display was actually viewed, and several of the areas that were activated in perception lit up in imagery as well (Kosslyn et al., 1993). Moreover, when asked to imagine either small or big letters while having their eyes closed, their brain activity changed in a way that resembled brain activity during perception of either big or small letters. As Kosslyn et al. (1993) point out, this last finding suggests that the causal conditions of visual imagery and perception are the same when differences in space are involved. This leads to a view of visual imagery as a quasi-perceptional phenomenon rather than a propositional one, directly contrasting Pylyshyn's view.

Summarizing neurobiological findings similar to those of Kosslyn et al (1993), Jeannerod and Decety (1995) defend that a similar relationship exists between motor imagery and movement preparation. The theoretical basis is that motor imagery involves strikingly similar peripheral neural activity in areas such as premotor cortex, lateral cerebellum, basal ganglia, and posterior parietal cortex (Morris et al., 2005), as well as in the supplementary motor area (Jeannerod & Decety, 1995). According to Jeannerod and Decety (1995), what distinguishes motor imagery is a process of physiological inhibition that impedes the motor neurons from firing. With such an approach, it becomes easier to explain studies in the psychoneuromuscular tradition that did not find muscular movement during motor imagery by claiming individual situational differences in inhibition (Jeannerod & Decety, 1995). However, it seems difficult to imagine how they would account for the results of Slade et al. (2002) in which the electro-muscular activation was different in amplitude and pattern compared to that of participants who physically performed the dumbbell task. Nevertheless, Jeannerod and Decety (1995) claim that the neurobiological and physiological similarities between motor imagery and movement should lead to similar enhancements in performance of a certain movement. Motor Imagery research strongly supports this claim, with MI by itself leading to less significant improvements than physical practice yet bigger improvements than no practice at all (see Morris et al., 2005; Ziegler, 1987). However, the knowledge underlying the neurobiological basis of more complex movements is still at a primitive stage, and more research is needed to clarify ambiguous findings in MI (Morris et al., 2005).

One important theoretical question underlies MI: Are motor images just weaker versions of actions? Or, are motor images “motor-like” mental phenomena? In summarizing their long series of studies on mental transformations, Shepard and Cooper (1986) concluded that visual images do not have a direct isomorphic relation to visual percepts, but a higher-order (indirect) one. Their argument is that propositional characteristics of visual images might be the bar. This view is consistent with Kosslyn’s definition of imagery as “internal representation that it is used in information processing” (Kosslyn, 1994, as cited in Holmes & Collins, 2001, p. 78). Considering this definition, a recent study by Coelho, Nusbaum, Rosenbaum, and Fenn (2012) investigated whether motor images are just weaker versions of the correspondent actions by using a golf-putting task. They had novice golf players physically or mentally putting either at different holes or at the same ones compared to a previous practice stage (nested design). The rationale was to see if task variability, which is known to improve performance in behavioral learning situations, would create different performance patterns between the imagery and the physical practice groups (Coelho et al., 2012). The results showed that task variability led to significantly better performances in the physical group but not in the imagery group (Coelho et al., 2012). The implication of these results is that it might be worth looking at how images differ from their respective percepts in order to better understand their relationship, rather than solely looking at their similarities. In short, functional equivalence may not be the only theoretical framework worth adopting.

The PETTLEP model. The PETTLEP model (i.e., Physical, Environment, Task, Timing, Learning, Emotion, and Perspective) of motor imagery develops out of the numerous neuropsychological studies showing similar cortical activity between motor imagery and action (Holmes & Collins, 2001). The model revolves around the position that since motor imagery and movement share similar activation patterns in the brain, they are functionally equivalent. However, in order for MI to provide performance enhancements that resemble those of physical practice, MI must resemble the actual movement or combination of movements as much as possible (Holmes & Collins, 2001). The indications for imagery provided by the model do not only cover the characteristics of the imagery itself, but also features of the physicality of mental practice. For instance, in the Physical component of the model, Holmes and Collins (2001) suggest to physically move while imagining, with movements that resemble the actual act and, possibly, with the specific sport implements. Although the model does not cover motivational imagery, in the Emotion component the authors advocate that imagery should involve the same arousal that the actual action evokes. More specifically, they attack the notion of relaxation while performing imagery through their guiding framework of functional equivalence. That is, since competitive scenarios imply elevated components of arousal from stress or pressure, moderate levels of arousal are recommended by the model (Holmes & Collins, 2001). Additionally, the authors suggest that Timing of imagery should reflect that of the actual action, in light of findings showing that rhythm is a determining factor in successful MI (Collins, Morriss, Bellamy, & Hooper, 1997, as cited by Holmes & Collins, 2001).

The MIIMS: A comprehensive model. The several combinations of imagery types, outcomes, and functions discovered in the last thirty years of research in sport psychology called for a comprehensive theoretical model. The most recent and comprehensive theoretical model of MI to date is the Motor Imagery Integrative Model in Sport (MIIMS, Guillot & Collet, 2008). This model takes into account several findings in sport psychology imagery research as well as theoretical and practical models in existence. The authors' goal was to address the weaknesses of previous models in creating one that covers the knowledge acquired thus far while pointing to new areas of investigation (Guillot & Collet, 2008). One of the main criticisms that Guillot and Collet express is that almost all the models of MI do not consider motivational *and* cognitive aspects of injury rehabilitation, despite the accumulating findings linking MI to faster recovery (but see Jackson, Lafleur, Malouin, Richards, & Doyon, 2001, for a model on injury rehabilitation). In fact, they argue that all five aspects of MI are involved in injury rehabilitation. One interesting aspect of the MIIMS is that it considers all the imagery modalities as part of MI, including olfactory, tactile, and auditory, proving the influence of functional equivalence on their model (Guillot & Collet, 2008). Also, they focus on Positive MI, which is closely related to Paivio's Motivational General-Mastery imagery and has motivational value in general. A recent study that justifies this position comes from Nordin and Cumming's (2005) work involving dart throwing and different variations of the script used to induce imagery. They found that facilitative scripts inducing CS or MG-M improved performance significantly in comparison to debilitative scripts inducing CS or MG-M. The difference here was much greater than between different imagery types, suggesting that positive imagery is a fundamental attribute of MI interventions (Nordin & Cumming, 2005).

The Issue of Imagery Perspective

One of the most researched aspects of MI has been the perspective of the imagery experience. Athletes often report experiencing two perspectives resembling either a first-person or a third-person visual perspective (Cumming & Ste-Marie, 2001). A first-person perspective, also called Internal Visual Imagery (IVI), involves imagining the observed scene from one's own eyes and within one's own body. Conversely, a third-person perspective, also called External Visual Imagery (EVI), involves imagining the observed scene from someone else's perspective in which one is present, much like watching a video of oneself. In the early days of MI research, confusion arose in regard to the relationship between Kinesthetic Imagery (KI) and the two perspectives. In fact, the experience of IVI, because of its point of view, was considered as including KI, while EVI was considered as strictly visual. Mahoney and Avener (1977) presented one of the first definitions of EVI and IVI:

> [In] external imagery, a person views himself from the perspective of an external observer . . . Internal imagery, on the other hand, requires an approximation of the real life phenomenology such that the person actually imagines being inside his/her body and experiencing those sensations that might be expected in the actual situation (p. 137).

It is easy to see how their definition of IVI includes movement-related references, especially in the last sentence. In their research, Maloney and Avener (1977) found that successful male gymnasts reported using IVI more than EVI. This finding led to a series of psychophysiological studies investigating the difference between the two perspectives. For instance, Hale (1982) found that IVI led to more integrated biceps activity than EVI when imagining a bicep curl. However, the instructions for IVI used the verb “imagine,” whereas the ones for EVI used the verb “visualize” (Hale, 1982), clearly underlying the difference in modality that is present in Mahoney and Avener (1977).

Findings about preference of IVI over EVI have not been consistent (Morris et al., 2005). For instance, Ungerleider and Golding (1991) found no significant preference between EVI, IVI, or a combination of the two among track-and-field athletes trying out for the 1988 U.S. Olympic team. Moreover, those athletes who made the team reported using EVI more often and experiencing more defined kinesthetic sensations from such perspective (Ungerleider & Golding, 1991). The conclusion Ungerleider and Golding (1991) drew was that preference in perspective might be different according to the event. Since then, an extensive amount of research has investigated how IVI and EVI differ in aiding performance among different sports (Morris et al, 2005). For instance, White and Hardy (1995) found that IVI helped retention of performance accuracy in a wheelchair slalom task, whereas EVI helped retaining accuracy in a gymnastic task. Testing tasks such as karate and a gymnastic routine, in which form is a fundamental part of the performance, Hardy and Callow (1999) found significant performance enhancement for participants training with EVI as opposed to IVI or no imagery training at all. Other studies found no significant difference between EVI and IVI on sports such as dart-throwing (Epstein, 1980) and cricket bowling (Gordon, Weinberg, & Jackson, 1994). Developing upon the considerations of White and Hardy (1995) on the functions of EVI and IVI, Morris et al. (2005) adhere to the idea that participants in sports such as dart-throwing, cricket, or golf putting (Roberts, Callow, Hardy, Woodman, & Thomas, 2010) involving both form and accuracy may benefit from the two perspectives in different ways.

Another framework that researchers have been utilizing to account for the ambiguity of perspective is the "openness" of the skill at hand. Open skills are those in which the environment is constantly changing and dictating the pace, whereas closed skills involve a stable environment and self-paced execution (McLean & Richardson, 1994). One prediction is that open skills would benefit more from EVI because of their ever-changing external conditions (McLean & Richardson, 1994). However, that contradicts White and Hardy (1995) since EVI improved both timing and accuracy on the closed task of gymnastic. Diametrically opposed results were found in a collection of studies comparing open and closed skills, with IVI or a combination of IVI and EVI leading to better performance on both open and closed skills, whether between different sports or within the same sport (Spittle & Morris, 1999; 2000; Fogart & Morris, 2003; both as cited by Morris et al., 2005). Looking at available research focusing on skill openness and perspective, it appears that form is a better (though still ambiguous) criterion to pinpoint advantages of either EVI or IVI.

Due to the ambiguity in findings concerning imagery perspectives, many theories are cautious in advocating either EVI or IVI. Interestingly, the PETTLEP model (Holmes & Collins, 2001) acknowledges the possible advantages of EVI, despite the seemingly diminished functional equivalence of this approach. In accordance with Hardy (1997), Holmes and Collins (2001) acknowledge the information-based function of MI, although their explanatory basis is more in agreement with Lang's bioinformational theory. In fact, Lang (1975, as cited in Holmes & Collins, 2001) claims that the strengthening of the links between stimulus and response propositions can start from any concept. The most famous neuroscientific finding that can serve as a theoretical connection between EVI and KI is that of mirror neurons, a special kind of visuomotor neurons discovered in studies on imitation learning with monkeys (Rizzolati & Craighero, 2004). In fact, there are significant portions of motor areas F1-F7 that fire when monkeys see the experimenter performing an action that needs to be learned, such as grabbing a cubic toy. These areas, among others, are active when monkeys physically perform the task (Rizzolati & Craighero, 2004).

Another theoretical attempt at explaining the ambiguities between IVI and EVI considers IVI as the default perspective and EVI as the alternative (Morris & Spittle, 2001). The default theory of imagery perspective is based on the reports from various studies suggesting that it is generally easier for participants to adopt IVI and harder to change IVI than EVI during perspective training (Morris et al., 2005). Morris and Spittle (2001) suggest that the likelihood of EVI to replace the default IVI depends on the experience of the individual. For instance, if an athlete has been extensively exposed to video as a coaching tool, EVI might be preferred. Experience could account for the equally distributed preference in IVI, EVI, or a combination of the two in the study by Ungerleider and Golding (1991), as different athletes experience different coaching techniques. In a recent study, Spittle and Morris (2011) attempted to train participants using IVI and EVI perspectives on two target skills–table tennis and dart throwing–that are remarkably different on how open they are. In fact, dart throwing has a constant, non-changing environment, which qualifies it as a closed skill, whereas table tennis, which presents an ever-changing environment, qualifies as an open skill. They found that it was easier for low-IVI imagers to be trained in IVI than for low-EVI to be trained in EVI, hence providing support for IVI as the default perspective. That said, the study had the limitation of only comparing imagery preferences after training without actually measuring imagery use or performance on the tasks (Spittle & Morris, 2011).

An alternative and novel approach to further understand the difference between IVI and EVI considers different personality characteristics as potentially intervening factors. A recent study in this direction comes from Roberts et al. (2010) who investigated differences in IVI and EVI in dart throwing and golf putting, sports in which neither perspective seems to be more advantageous as far as performance enhancement is concerned. The authors investigated the interaction of perspective with scores on narcissism and self-enhancement opportunities. The study showed that people high on narcissism improved from a low to high self-enhancement condition (presence or absence of rewards for the best performers) only when their mental practice was characterized by EVI (Roberts et al., 2010). Presumably, narcissist athletes gain more by looking at themselves rather than the target of their action, assuming the activity is extrinsically rewarding. Beside this purely speculative consideration, the finding is one of the first of its kind, considering personality factors as determinant, aligning with Hardy's (1997) suggestion of personalizing the imagery technique onto the athlete.

The Role of Movement

There is no doubt that athletes benefit from physical practice of the actual athletic movement. At the same time, athletes often perform movements and gestures that resemble the actual act. Common examples are routines of basketball players before foul-shooting and pre-swing routines of golfers. An interesting question is whether combining these routines with MI can improve its efficacy. Practically, can implementing movement to imagery increase the performance-enhancing qualities of MI? In accordance with the PETTLEP model, MI should resemble actual performance as much as possible, and its proponents advocate moving while imagining (Holmes & Collins, 2001). The rationale is that performing movement strengthens the memory trace thanks to similar brain activation and afferent feedback (Holmes & Collins, 2001). The movement aspect, together with wearing sporting clothing and handling sport equipment is part of the *Physical* aspect of the

PETTLEP model (Holmes & Collins, 2001). Nevertheless, more research has been dedicated to the contextual part of the physical aspect of the PETTLEP model (Guillot, Moschberger, & Collet, 2013). For instance, Smith, Wright, Allsopp, and Westhead (2007) found that imagery training that included hockey clothing enhanced performance more than traditional imagery (i.e., non-PETTLEP) or no imagery at all in a hockey penalty flick task.

Spontaneous movements and gestures have been shown to improve performance in cognitive tasks, such as spatial rotation tasks (Chu & Kita, 2011). Although MI and spatial problem solving should not be confused (Guillot et al., 2013), Chu and Kita (2011) suggest that their findings can extend to similar cognitive processes, such as MI.

Surprisingly, only one study has investigated the interaction of movement and MI on performance enhancement. Guillot et al. (2013) had competitive high jumpers perform ten jumps, each preceded by either a dynamic or static MI session. The experiment showed that dynamic imagery resulted in technically-improved jumps (as judged by expert coaches), closer time congruence between imagery and actual jump execution, and more cleared jumps (Guillot et al., 2013). As the authors suggest, limitations of this study included the small sample size (12 athletes) and the within-subject design (Guillot et al., 2013).

Current Study

The current study presents different opportunities to further the understanding of the relationship between MI and performance and the way in which such relationship can be investigated. The choice of athletic task here is dart throwing due to its extensive use in the imagery literature and the fact that it is easily approachable by the student population. A methodological novelty of this study involves the use of External and Point-of-View videos as the sole perspective-inducing method. Although perspective videos have been used in previous influential research (see White & Hardy, 1998), this study will have a perspective-neutral imagery script. Additionally, the IVI and EVI groups will respectively only see the Point-of-View video and the External video, as opposed to a combination of them. Another methodological novelty of this study involves a second administration of the imagery ability test (MIQ-3, Williams et al., 2012) after the experiment has been completed. The purpose of this procedure is twofold. On one hand, it will function as the post-experiment questions used in Nordin and Cumming (2005) to assess the ease with which participants formed images during the experiment. On the other hand, this second administration will give an opportunity to address the question of whether imagery training can improve general imagery ability as assessed by the MIQ-3. It is hypothesized that an improvement in internal visual imagery will occur for participants in the IVI condition; an improvement in external visual imagery will occur for participants in the EVI condition; and an improvement in kinesthetic imagery will occur for participants in any of the four conditions.

The main questions this study is aiming to address involve the performance enhancement ability of different imagery interventions across numerous practice trials. Specifically, it is hypothesized that any imagery intervention will lead to an improvement of performance that will exceed that of the control group. This prediction is supported by the well-grounded finding in sport psychology that MI is an effective performance enhancement technique (Morris et al., 2005). In accordance with the Physical component of the PETTLEP model and recent findings by Guillot et al. (2013), it is hypothesized that a main effect of movement will be found. Specifically, imagers in the movement condition will improve their dart-throwing performance significantly more than participants in the non-movement condition across the four trials. As far as difference in perspective, it is hypothesized that no perspective main effect will be found. This prediction is in line with findings by Roberts et al. (2010) and the character of dart throwing as a sport involving both form and accuracy, features that generally benefit from EVI and IVI respectively. Finally, it is predicted that there will be an interaction between perspective and movement. Specifically, it is hypothesized that participants in the IVI condition will benefit more from dynamic imagery than participants in the EVI condition. This prediction is congruent with findings suggesting that the more components of the PETTLEP model are involved in the imagery intervention, the more effective imagery is for performance enhancement purposes (Smith et al., 2007).

Method

Participants

The sample consisted of 80 undergraduates at the University of Louisiana at Lafayette, recruited either through the subject pool system or via promotional flyers, in exchange for extra credit in their undergraduate psychology course. This sample size led to 16 participants per condition (four conditions) and the same number for a control group that did not receive imagery training.

Instrumentation

A Viper Shot King Bristle Dartboard (an official-sized dartboard) and Harrows Black Arrow Steel Tip Darts (23-Gram) were used for the dart-throwing task. The dartboard had metal wire dividing it in concentric circles, but it was repainted with green acrylic paint in order for participants to focus on the red bullseye. In an effort to maintain consistency in the imagery literature, the division used by Nordin and Cumming (2005) was adopted. The bullseye, which is the innermost circle, had a radius of .75cm. The respective difference of the radii of the successive concentric circles were as follows: 1cm; 4.5cm; 3.5cm; 1cm; 5.5cm; 1cm; and 5.5cm. A dart landing on the bullseye scored 8 points, with a detraction of one point per outer ring, up to the outmost ring which had a value of 1 point. Darts that miss the dartboard scored zero (see Appendix B). The assessment trial prior to the imagery condition had participants throwing at a distance of 213cm from the dartboard. Departing from previous literature (Nordin & Cumming, 2005; Williams & Cumming, 2012), the distance for the assessment trial remained the same for all subsequent trials.

A GoPro Hero3 Camera was used for the Point of View perspective video. The actor, a local American Darters Association ranked player, performed the dart-throwing task while wearing a neoprene head mount with the GoPro Hero3 camera attached to it. Simultaneously, a CamOne Infinity video camera mounted on a tripod recorded the scene for the External View perspective video, with the camera directed perpendicular to the throwing trajectory.

Measures

Activity questionnaire. The questionnaire was administered on site and included basic demographic information such as age, gender, and handedness. Additionally, experience in organized sport was assessed, together with the years of experience and the sport discipline. Also, self-reports of perceived expertise in various sport disciplines and games were assessed using 7-point Likert scales. The sports considered were snow skiing, golf putting, golf driving, chess, skeet shooting, bowling, skateboarding, and dart throwing. Together with perceived expertise, activity engagement of potential participants was assessed (using 6-point Likert scales) by asking about habitual frequency and the last time they performed the activity. Since participants in this study performed a dart-throwing task, respondents who usually plays less than once per week were considered eligible to take part in the study. Finally, the frequency of exposure to and the general interest about the above mentioned activities were assessed using 6-point Likert scales.

Movement Imagery Questionnaire-3. The MIQ-3 (Williams et al., 2012) is a questionnaire assessing the ease of forming clear kinesthetic and visual images. The decision to use this measurement is based on its ability to test for differences in internal and external visual imagery, an ability not present in the MIQ-R (Hall & Martin, 1997) or MIQ-RS (Gregg, Hall, & Butler, 2010). The MIQ-3 was chosen over the revised version of Vividness of Movement Imagery Questionnaire (VMIQ-2, Roberts, Callow, Hardy, Markland, & Bringer, 2008), a similar, often-used measure also testing for differences between internal visual, external visual, and kinesthetic imagery, because of the difference in instructions, the latter stressing levels of “vividness,” and the former stressing “ease.” The impression is that "vividness" is used in everyday language as referring to visual images, which might be a source of confusion concerning kinesthetic imagery instructions. The MIQ-3 appears to avoid this problem as it specifically asks for "ease to feel" or "ease to see" (Williams et al., 2012). Through composite reliability on the measures of external visual, internal visual, and kinesthetic imagery, the MIQ-3 has been shown to have satisfactory internal reliability ($r > .9$). At the present time, test-retest validity has not yet been assessed due to the novelty of the measure. However, the MIQ-RS from which the MIQ-3 was developed showed good test-retest reliability, with Pearson's coefficients of $r = .83$ for the visual imagery subscale and $r = .73$ for the kinesthetic subscale (Gregg et al., 2010).

Performance. Performance was determined by the landing position of the dart on the dartboard. The dartboard was divided into eight concentric circles, with the innermost circle having a value of eight points, and a one-point decrease for each successive outer circle.

Manipulation check. Following the end of Trial 2, participants completed a mid-experiment manipulation check. Participants were asked (a) whether they used imagery as instructed by the experimenter, (b) if they followed the steps presented by the audio instructions, and (c) if they always aimed for the bullseye. Answers to these three questions were given on a Likert scale from 0 (not at all) to 3 (yes, in every part). Additionally, the perspective of their imagery was assessed through an 11-point Likert scale, with 0 indicating a fully internal view and 10 indicating a fully external view. Finally, the perceived helpfulness of the imagery trials was assessed through a 5-point Likert scale, with 1 indicating imagery as completely unhelpful, and 5 as completely helpful.

Post-experiment manipulation check. Following the end of the last throwing trial, all participants completed a manipulation check. The first five questions were the same ones described in the manipulation check. Additionally, participants were asked whether they used strategies other than the instructed imagery to improve their performance. Options were provided, such as self talk, goal setting, etc, but space was also provided for open answers.

Procedure

Introduction. Participants were welcomed outside the laboratory and given information about the experiment together with an informed consent form, followed by the Activity Questionnaire. The reason for keeping them outside was to avoid any biases in the responses to the Activity Questionnaire due to the sight of the dartboard in the laboratory. Random assignment determined whether the participant was in one of the four imagery groups or in the control group. The informative section contained the definition of imagery used in a study on the use of imagery by athletes (White & Hardy, 1998). This definition was chosen due to its extensive use in the literature and its simplicity. Next, the Movement Imagery Questionnaire-3 (Williams et al., 2012) was administered to assess the participant's ability to form internal and external visual images, and kinesthetic images. If participants were assigned to the imagery group, they were informed that the purpose of the study was to assess how different imagery techniques improve athletic performance. It was also specified that the athletic task that they were going to perform was dart throwing. If participants were assigned to the control group, they were told that the goal of the study was "to gain a better understanding of how different motor techniques can help athletes improve their performances." In this case, there was no mention of imagery nor was the MIQ-3 administered.

Pretest. After the completion of the introductory part, an assessment of the participant's dart-throwing ability took place. Participants received some elementary technical instructions for correct throwing, and were instructed to always aim at the bullseye. Next, they performed the assessment trial consisting of 15 throws from a distance of 213cm (seven feet). The number of throws had been selected because it allows participants to be accustomed with the task while not making it boring (Van Raalte et al., 1995). Once this phase was over, participants watched a video from either a Point of View perspective or an External View perspective, depending on which imagery condition they happened to be in. To maintain consistency, the two videos were filmed simultaneously. The actor was a local professional dart player, showing the correct stance, technique, and execution, as a background voice explained the task. None of the videos were shown to participants in the control group.

First trial. At the end of the video, participants were randomly assigned to one of two movement conditions. These conditions involved the presentation of an imagery script that the participant heard through speakers. The script was an adaptation of the Cognitive-Specific facilitative script used by Nordin and Cumming (2005). The script contained a balanced combination of internal and external visual and kinesthetic imagery instruction. Such balance was fundamental as the direction of the visual imagery (internal vs. external) was to be solely induced by the video that the participant was assigned to. Also, the script reiterated the fundamental technique instructions presented before pretest. Participants in the non-movement condition were asked to stand behind the throwing line with their arms close to their sides and their eyes closed, and instructed to be relaxed while maintaining that stationary position. Participants in the movement condition were also asked to stand behind the throwing line with eyes closed, but they were instructed to move *as if they were throwing*. Since these instructions were given in written form before the hearing of the script, no constraints were placed on when the participant had to move, nor on when the participant had to stop imaging and start the dart-throwing task. That is, the imagery training started at the hearing of the script and ended whenever the participant was ready to throw. That said, this length of time was recorded, starting from the beginning of the imagery script and ending at the release of the first throw. Once participants were ready, the dart-throwing task started, finishing after all 15 darts were thrown. The experimenter recorded the score after every 3-dart set. At the end of the task, a 2-minute break would take place to allow the participant to rest. The participant was asked to sit in a room adjacent to the experimental room and asked to relax.

The control group. The procedure for the control group differed in a few aspects. In order to avoid problems related to the imagery groups receiving something (i.e., an audio script) and the control group not receiving anything, participants in the control group also listened to an audio script. However, this script did not involve any imagery use, but simply covered the technical aspects of dart throwing that were covered by the imagery script. The goal was for the control group to receive the same technical dart-throwing knowledge, hence further isolating the role of imagery treatment for the imagery groups. The control group also took a 2-minute break, but in order to prevent participants from thinking back to their previous throws, which can facilitate spontaneous mental practice (Nordin & Cumming, 2005) due to the similarities between Motor Imagery and visual working memory (Borst, Ganis, Thompson, & Kosslyn, 2011; Sutton, 2012), they performed a distraction task. This task consisted in calculating scores of imaginary 501 games. 501 is the most popular game in professional dart leagues, and it consists in scoring precisely 501 points with the fewest number of darts. Participants were asked to choose a mock 501 game from a list of twelve, and once the experimenter announced the score of the individual dart (i.e., triple seventeen), they had to subtract the given number. If they struggled with the arithmetic, the experimenter provided help. The task was similar to the classic counting back by seven from a 4-digit number, which has been used in previous research (Nordin & Cumming, 2005; Cumming et al., 2006).

Subsequent trials. Three trials followed the first one for a total of four trials. The procedure was identical to that used for the first trial. At the end of the second trial, imagery participants received a manipulation questionnaire to check if they followed the instructions given. At the end of the fourth trial, all participants were asked to complete a final manipulation check questionnaire. Imagery participants answered the same questions as those presented after Trial 2, followed by additional questions aiming at understanding whether other techniques were used apart from motor imagery. Additionally, the questionnaire contained items addressing the visual perspective experienced by the participant. After this, the MIQ-3 was administered again to assess possible changes in imagery ability. Finally, participants were debriefed. Participants in the control group were also given a questionnaire after the last trial. However, this questionnaire only asked whether they always aimed at the bullseye and what strategies, if any, they found themselves using before throwing. Visual imagery was one of the options provided. After the completion of the questionnaire, the experimenter debriefed control participants, explaining the real nature of the study.

Results

Preliminary Analyses

Activity questionnaire. The sample for this study was representative of the available population, which almost entirely included students of introductory psychology classes. That is, the average age of students was 20.6 (*SD* = 3.99), while for gender more than two thirds of the sample consisted of females (69%). Also, about 8% of the sample was left handed. One of the important functions of this questionnaire was to have an initial understanding of dart-throwing ability and frequency of potential participants. The entire sample reported to be "somewhat skilled" or below, with 65% reporting either neutral skill level or lack of skill. Additionally, all participants reported playing darts once per month or less, with the vast majority (81%) having played over a month prior to the experiment. Also, 89% of the sample reported being exposed to darts once every three months or less, while 66% of participants reported low levels of interest or even disinterest in the activity. Based on these factors, the entire sample was retained.

Imagery ability. Since the Movement Imagery Questionnaire 3 was delivered two times, the average of the two scores was used for any analysis involving imagery ability. Test-retest reliability was satisfactory for kinesthetic imagery, $r(62) = .83$, $p < .01$, and for internal visual imagery, $r(62) = .75$, $p < .01$, while it approached satisfactory levels for external visual imagery, $r(62) = .66$, $p < .01$. To check whether experimental groups differed in imagery abilities, three one-way ANOVAs were performed. As Table 1 shows, there was no significant difference among the groups in internal or external visual imagery ability, or kinesthetic imagery ability. Following the criterion used by Nordin and Cumming (2005), participants scoring an average of five or higher across the three abilities were labeled as having "high imagery ability," whereas participants scoring less than five were labeled as

Table 1

Imagery Ability and Manipulation Checks Tests for Imagery Groups and Contr

	Scores						
	IVI NM		IVI M		EVI NM		E
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*
MIQ-3 EVI	5.45	0.83	5.35	1.13	5.85	1.03	5.8
MIQ-3 IVI	5.43	1.07	5.76	0.86	5.47	1.33	5.4
MIQ-3 KI	5.43	1.01	5.52	1.02	5.66	0.92	5.7
Following imagery instructions	1.78	0.45	2.31	0.48	2.13	0.67	2.1
Following imagery steps	1.94	0.48	2.28	0.45	2	0.55	2.2
Aiming at bullseye	2.13	0.59	2.53	0.53	2.38	0.62	2.3
Imagery helpfulness	3.22	0.8	3.88	0.92	3.94	0.87	3.5

having "low imagery ability." In this study, 49 participants scored five or more, whereas 15 participants scored less than five.

ANOVAs were performed using pre-imagery performance, the mean and standard deviation of dart-throwing trials, and mean time of imagery prior to throwing as dependent variables. High and low imagers did not different significantly in any of these variables (see Table 2). Finally, the percentage of participants with different imagery ability did not differ across the four experimental groups, $\chi^2(3, N = 64) = 0.26$, $p = .97$. On the basis of these analyses, the entire sample was retained.

Table 2

Imagery Ability and Performance Measurements

	Imagery ability				Difference between means		
	Low		High				
Measure	*M*	*SD*	*M*	*SD*	df	*F*	*p*
Assessment trial (Means)	4.08	0.87	4.17	0.88	1,62	0.11	0.74
Assessment trial (SD)	1.79	0.42	1.68	0.47	1,62	0.74	0.39
Trials averaged (Means)	4.55	0.69	4.41	0.76	1,62	0.43	0.51
Trials averaged (SD)	1.52	0.35	1.52	0.35	1,62	0	0.98
Average imagery time	155.92	3.07	157.2	3.28	1,62	1.81	0.18

Gender differences. In order to explore gender differences, ANOVAs were used with the dependent variables described above for imagery ability. As may be seen from Table 3, there was a gender effect in both ability, $F(1,62) = 27.12$, $\eta_P^2 = .3$, $p < .01$, and performance, $F(1,62) = 41.04$, $\eta_P^2 = .4$, $p < .01$, with males performing significantly better than females. However, the mean imagery time prior to performance trials did not differ ($F < 1$). To investigate whether there were differences in imagery interventions across gender, additional ANOVAs examined the difference in means and standard deviations between the assessment trial and the average across imagery trials. In both cases, the interaction of gender and trial for means and standard deviations proved nonsignificant ($F < 1$). Since these analyses showed no difference in how imagery affected the two genders across trials, gender was not considered as a factor in subsequent analyses.

Table 3

Gender Differences in Performance Measurements

	Gender				Difference between means		
	Female		Male				
Measure	*M*	*SD*	*M*	*SD*	df	*F*	*p*
Assessment trial (Means)	3.82	0.77	4.86	0.7	1,62	27.12	< .01
Assessment trial (SD)	1.85	0.43	1.38	0.35	1,62	17.95	< .01
Trials averaged (Means)	4.13	0.63	5.13	0.44	1,62	41.04	< .01
Trials averaged (SD)	1.66	0.3	1.21	0.24	1,62	34.29	< .01
Average imagery time	156.8	2.87	157.11	4.04	1,62	0.12	0.73

Manipulation checks. Four ANOVAs were performed to investigate whether there were group differences in participants following the experimenter's instructions, following imagery steps, aiming at the bullseye, or in participant's perceived helpfulness of imagery (see Table 1). Since these questions were asked both after the first two trials and at the end of the experiment, the dependent measure was the average of the two responses. Differences between groups in these four responses proved nonsignificant. Eighty-nine percent of imagery participants reported using other strategies in addition to motor imagery. Of these, 64% reported using goal setting, 60% using positive self-talk, 12% using negative self-talk, and 21% other kinds of strategies. Chi-square analyses were performed to detect any differences in opted strategies between imagery and control groups, but none were found. Among control participants, all reported using some strategy while throwing. Specifically, 75% reported using visual imagery as a strategy, 63% using positive self-talk, 56% using goal setting, and 25% using other kinds of strategy.

Reported imagery perspective. Participants were asked the location of their visual imagery (i.e., internal or external) on a 11-point Likert scale, with 0 being "completely internal" and 10 being "completely external." This question was asked both after Trial 2 and at the end of the experiment. Considering a score of 5 as ambiguous perspective, 73% of the sample maintained a consistent perspective throughout the experiment. However, only 34% maintained the same exact perspective score throughout the experiment. In order to understand what could account for such a recurrent change, I decided to add some questions to the Post Experiment Manipulation Check midway through data collection. Specifically, these questions explicitly asked the difference between the point of view of the video and the participant's imagery perspective, and the degree to which participants found themselves switching between different perspectives. In both cases, these questions were asked addressing the early stages and the final stages of the experiment. Seventy-nine percent of participants experienced a shift in perspective directed towards the perspective of the video, while 56% reported switching perspective more frequently as the experiment proceeded (N = 34). Since these questions occurred at the end of the experiment, they could not have affected earlier dart-throwing performance.

Main Analyses

The main question this study tried to address was whether different motor imagery perspectives and the presence or absence of movement had an effect on dart-throwing performance and precision patterns across multiple trials. To answer this question, repeated-measures analyses were used with the means and standard deviations of dart-throwing trials as the repeated measure to detect differences in performance and precision respectively. The between-S factors were movement, video condition, and perceived perspective as reported by participants. In the case of performance, the performance of the assessment trial was used as a covariate, whereas in the case of precision, the standard deviation score of the assessment trial functioned as the covariate.

Preplanned linear contrasts. To answer the question of how imagery training would change performance and precision across trials, preplanned linear contrasts were used on the means of the imagery groups and the control group, adjusted for their ability as assessed by the assessment trial. Of course, the hypothesis here was that there would be improvement across trials, but that the improvement would be greater for the imagery groups. Concerning performance as assessed by mean adjusted accuracy, an overall linear trend was found, $F(1,74) = 7.452$, $\eta_P^2 = .09$, $p < .01$. However, this trend did not differ between imagery groups and control, $F(1,74) = 1.182$, $p = .28$. A different pattern emerged for precision. Although there was no overall change as a function of trial, this turned out to be due to the two conditions showing opposite trends. As Figure 1 shows, imagery participants steadily improved their precision, $F(1,62) = 9.723$, $\eta_P^2 = .14$, $p < .01$. Despite control participants progressively became less precise after Trial 2, this tendency was not predicted by a linear trend, $F(1,14) = 1.097$, $p = .31$, nor by a quadratic trend, $F(1,14) = 2.75$, $p = .16$. However, evidence of different precision trends between imagery and control came from significant linear trends of opposite slopes, $F(1,74) = 4.826$, $\eta_P^2 = .07$, $p = .03$.

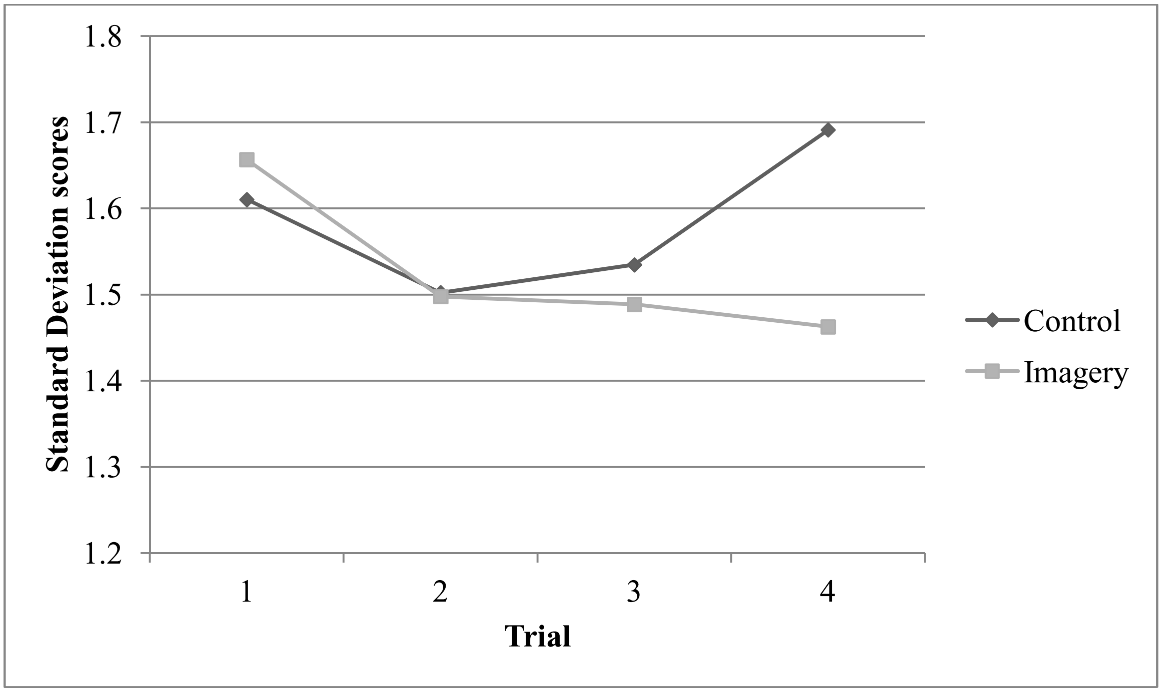

Figure 1. Precision scores of Imagery and Control groups over four trials.

Note: The graph shows a significant Trial x Imagery linear trend. Lower scores indicate better precision.

The same procedure was used to answer the question of how different imagery training would change performance and precision across trials. The analysis was again over the four trials, but this time it only included the four imagery groups in a 2 x 2 between-S design with movement and perspective as factors. Concerning performance, despite a highly significant overall linear trend for the averaged imagery condition, $F(1,59) = 7.86$, $\eta_P^2 = .12$, $p < .01$, this trend did not moderate as a function of internal or external video condition ($F < 1$) or movement and non-movement condition, $F(1,59) = 2.34$, $p = .13$. To understand whether the internal video condition benefited more from movement than the external video condition, the linear trend of these two groups was compared. However, it failed to reach significance ($F < 1$). As for precision, no overall significant linear trend was found, nor did the individual experimental groups differ in their linear trends.

Finally, the same procedure was used, this time using the imagery perspective as reported by participants instead of the video condition (the six participants who experienced an ambiguous perspective were excluded from these analyses). In the case of performance, a significant overall linear trend occurred as in the analysis reported above, $F(1,53) = 9.57$, $\eta_P^2 = .18$, $p < .01$. And as before, no linear trends were found in the corresponding precision data.

Analyses over four trials. A split-plot ANCOVA with performance as the repeated measure and the presence of imagery practice showed neither a main effect of imagery vs. control condition, $F(1,77) = 0.19$, $p = .66$, nor of trials, $F(3,231) = 2.23$, $p = .09$, nor an interaction of these ($F < 1$). The corresponding analysis for precision also proved nonsignificant (all Fs < 1).

The next analysis involved a three-way ANCOVA of performance in just the imagery groups that used video perspective and movement conditions as between-S factors, and trial as a repeated measure. The only significant finding here was a trial effect reflecting improvement over trials, $F(3,177) = 4.31$, $\eta_P^2 = .05$, $p < .01$.

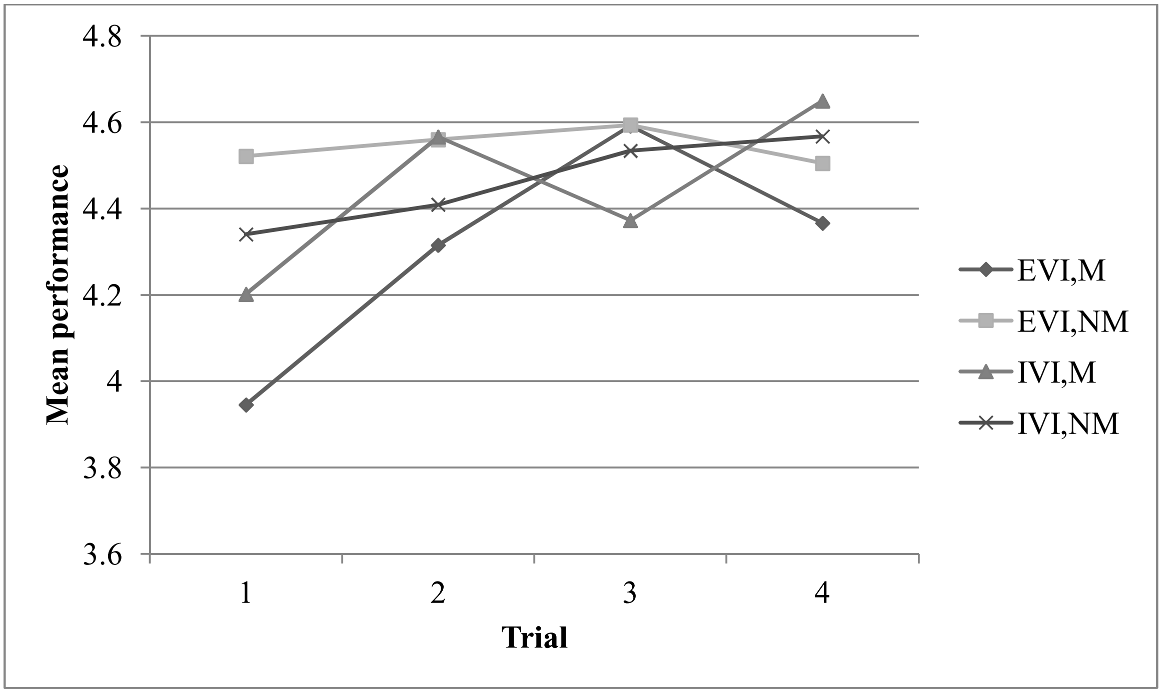

Figure 2. Performance scores of four experimental groups over four trials.

Note: The graph shows a significant Trial main effect. EVI and IVI stand for External and Internal Visual Imagery, whereas NM and M stand for Non Movement and Movement.

The corresponding ANCOVA on precision, in contrast, exhibited no effects that reached significance.

Finally, data were analyzed using perceived perspective instead of video condition, averaging over the two reports midway and at the end of the experiment, and excluding participants who perceived ambiguous perspective. These analyses exhibited the same patterns: a trial effect for the performance data, $F(3,159) = 5.65$, $\eta_P^2 = .1$, $p < .01$, but no effects for the precision data (all Fs < 1).

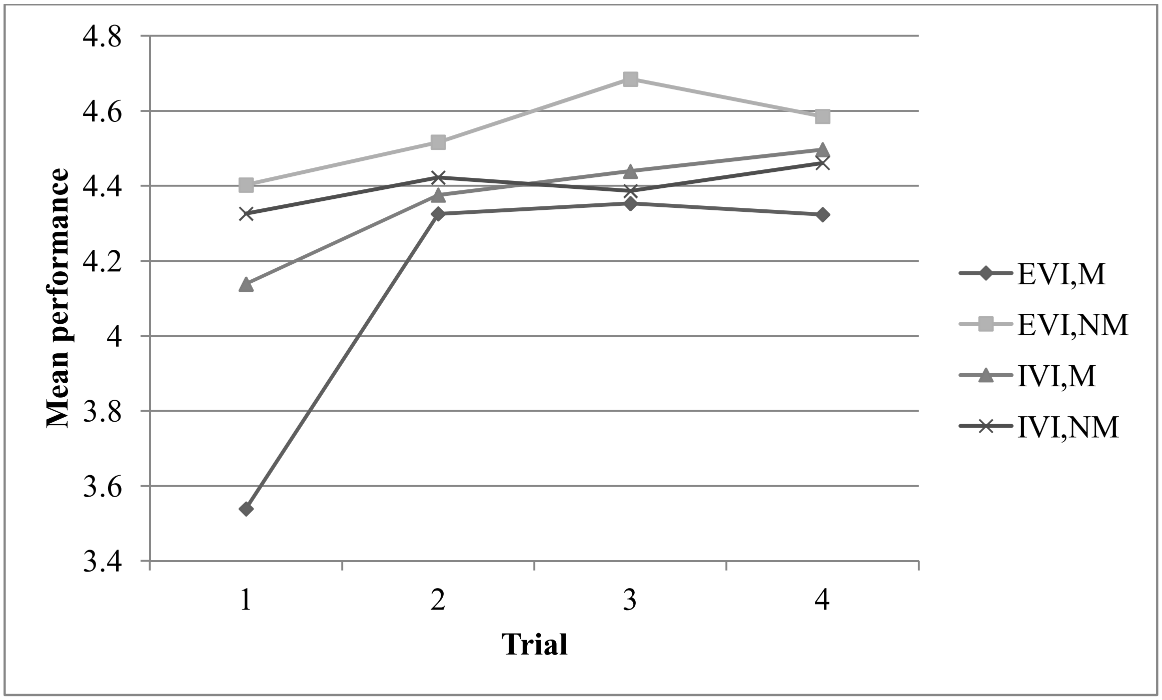

Figure 3. Performance scores of four groups over four trials (perceived perspective).

Note: Groups divided according to Movement condition and Perceived Perspective, showing a significant Trial main effect. Higher scores indicate better performance. EVI and IVI stand for External Visual Imagery and Internal Visual Imagery, whereas NM and M stand for Non-Movement and Movement. Higher scores indicate better performance.

Exploratory Analyses over Two Trials

Although the earlier results failed to indicate any interactions with trial, I compared the different pairs of trials to further assess the possibility of imagery, imagery perspective, and movement across trials. The reader should be warned that the following results ought to be regarded as purely suggestive, due to the possibility of a Type 1 error. In a general way, they should be considered as exploratory analyses for follow-up research aimed at determining if they replicate. All the following analyses were ANCOVAs, with mean and standard deviation score on the assessment trial as covariates respectively for the performance and precision analyses.

Trials 1 and 4. The reason behind the choice of this pair of trials was to roughly compare the results of the present study with previous literature looking only at pre- and post-test scores. The analyses of performance verified the lack of difference between control and imagery groups. However, a significant interaction of group with trial was obtained in the analysis of precision due to imagery participants becoming more precise while control participants showed the opposite trend, $F(1,77) = 5.1$, $\eta_P^2 = .06$, $p = .03$. Looking only at the four imagery groups, participants who watched the internal video became more precise over trials than those who watched the external video, $F(1,61) = 4.76$, $\eta_P^2 = .08$, $p = .03$. Also, movement participants performed worse than non-movement participants in the first trial, but then improved to slightly surpass non-movement participants by Trial 4. However, this trial by movement interaction failed to reach conventional levels of significance, $F(1,61) = 2.98$, $p = .09$.

Trials 1 and 2. The reason behind the choice of this pair of trials was to understand the trends early on in the experiment before the administration of the first manipulation check. No differences were found for either performance or precision between control and imagery groups (all *F*s < 1). A similar patter occurred in the performance data involving the interaction of movement with trial as that described in the comparison of Trials 1 and 4, but as earlier, it also proved not significant, $F(1,61) = 3.39$, $p = .07$.

Trials 3 and 4. The reason behind the choice of this pair of trials was to understand the trends later on in the experiment after the administration of the first manipulation check. In the comparison of Trials 3 and 4 the control and imagery groups again failed to differ. There was a trial by imagery interaction reminiscent of that found in the comparison of Trials 1 and

4, but it failed to reach conventional levels of significance, $F(1,77) = 2.1$, $p = .15$. As for video perspective, internal video participants became more precise, but external video participants became less precise, $F(1,61) = 5.13$, $\eta_P^2 = .08$, $p = .03$.

Post Hoc Analyses

Effectiveness of the video. Effectiveness of the video on imagery perspective as perceived by participants was conceptualized in three ways. The first conceptualization, named *average intervention effectiveness*, considered the treatment effective if the average "direction of imagery" response corresponded to the video perspective. Specifically, if the average fell below 5 for point-of-view video and above 5 for external video, then the treatment was scored as successful. In case of an average of 5, only the second "direction of imagery" response was used as indicative of imagery perspective. In this case, the video proved to be effective above chance, $\chi^2(1, N = 64) = 9$, $p < .01$, odds ratio = 4.84. In particular, the internal video proved to be more successful at inducing the correspondent imagery perspective than the external video ($p < .01$).

The second conceptualization of effectiveness, named *effective imagery*, considered changes from one side to the other of the perspective continuum. That is, if imagery perspective went from anything to that of the video across the two questionnaires, or if it remained the same and it matched the video, then the treatment was considered successful. Similarly to the first conceptualization, the video proved to be effective above chance, $\chi^2(1, N = 64) = 5.19$, $p = .02$, odds ratio = 3.29, with the internal video being more successful ($p = .02$).

The third conceptualization of effectiveness, named *effectiveness of direction*, considered the change in direction of the perspective. So, if participants' perspective score decreased from the first report to the second and they saw the internal video, then the video was considered successful, regardless of the actual perspective. For instance, if a participant watched the internal video and switched from a strong external perspective to a weaker one, then the video would be considered effective. However, if the same participant happened to experience a switch from a strong internal perspective to a weaker one, then the video would not be considered effective. With this conceptualization, the video did not predict effectiveness beyond chance. However, a gender effect was found, $\chi^2(1, N = 64) = 5.42$, $p = .02$, with males' perspective shifting more towards that of the video ($p = .02$). As opposed to the previous two conceptualizations of effectiveness, here imagery ability proved to be a significant predictor. In fact, logistic regression showed that mean kinesthetic imagery ability predicted the effectiveness of the video, $\chi^2(1, N = 64) = 5$, $p = .03$, odds ratio = 0.54, with higher kinesthetic imagery ability lowering the odds of the video influencing the direction of imagery perspective.

Discussion

Summary and Discussion of Findings

The main goal of this study was to understand the role of movement and imagery perspective on dart-throwing performance and precision across several trials. The question posed here was slightly different from that in previous literature, since imagery practice occurred before each of the several trials, as opposed to occurring between pre- and post-test trials. Additionally, the effect of different videos on performance, precision, and imagery perspective was analyzed, in order to understand the impact of visual aids on visual imagery and sport performance.

The role of movement. Contrary to prediction, participants doing dynamic imagery (i.e., moving while imagining) did not improve performance or precision across trials more than participants doing static imagery. Even more surprising was the performance trend early in the experiment, which suggested that dynamic imagers performed worse at first and eventually rose and plateaued with static imagers midway through the experiment. The lack of effect of movement contrasts with findings from Guillot et al. (2013) in which competitive high jumpers using dynamic imagery cleared more jumps and improved technical aspects of the execution. The difference between this experimental design and Guillot et al. (2013) is evidenced by movement being a between-S factor in the present study, which could be a reason for the different findings. Additionally, Guillot et al. (2013) used a sample from a population of competitive athletes, as opposed to the present study that used university students not involved in competitive dart throwing.

Throughout the data collection process, a limitation concerning the imagery script emerged. That is, the imagery script used for participants did not lend itself to natural gestures that resembled the smooth act of throwing. There is a recent argument that imagery scripts should be personalized and follow the natural sequence of events of the imagined movement (Williams, Cooley, Newell, Weibull, & Cumming, 2013). Additionally, the instructions given to participants required them to enact specific movements in the script but since the script was not written specifically for dynamic imagery, the consequent gestures that ensued were somewhat unnatural. For instance, the script involved raising one's arm to throwing position, but subsequent motion-related instructions were not presented until about a minute later, leaving the participant in an awkward position, and failing to integrate one motion smoothly into another. One future direction this suggests is examining the effects of dynamic versus static imagery through adapting specific scripts.

The role of perspective. Naturally, an important aspect of visual imagery (and consequently of motor imagery) is the visual perspective from which the scene is visualized. As predicted, no significant differences in performance or precision between perspectives emerged in this study. To increase the validity of this finding, this study considered participant's reported perspective as the true perspective. The fact that perspective did not affect performance confirms previous imagery literature using dart-throwing (Epstein, 1980; Roberts et al., 2010), a result also found in other sports in which aim is crucial, such as cricket bowling (Gordon et al., 1994) or golf putting (Roberts et al., 2010).

Of course, no ratings of form were collected in this study. Nevertheless, some aspect of accuracy was addressed via assessing precision, the change in standard deviations across trial. There was some hint that internal imagers may have been more precise towards the end of the experiment, though this improvement failed to achieve significance. One limitation of this approach is that a standard deviation score does not contain information about where the dart landed, so ideally one could become more precise at performing worse. That being said, in this particular study standard deviations became smaller as mean performance increased, suggesting participants became more precise as they performed better.

The role of videos. One of the innovative aspects of this experiment was the use of videos from different points of view as the sole perspective-inducing method. Interestingly, external or internal visual imagery ability did not predict the effects of the video on participants' perceived perspective. If one considers effective the average perspective throughout the experiment, the video condition was the only significant predictor for this value. Likewise, only the video condition predicted shifts in perceived imagery throughout the experiment that ended with participants' perspective and video perspective coinciding. That said, it should be noted that the video did not always cause participants to adopt the correspondent imagery perspective. Consequently, use of a video by itself is not sufficient to induce a certain perspective. In previous work, imagery scripts carried the burden of inducing a certain imagery perspective (Epstein, 1980; Roberts et al., 2010), and this practice has been encouraged (Williams et al., 2013). Hence, the findings of this experiment point to some limitations on how visual aids can affect imagery perspective.

An unforeseen finding regarding the role of video was that kinesthetic imagery ability seemed to play a greater role in predicting the shift to the video's perspective than did imagery ability. Specifically, participants lower in kinesthetic imagery ability were more likely to shift towards the perspective of the video. The interpretation of this result is not straightforward, especially in light of findings suggesting that kinesthetic and visual imagery are distinct abilities (Morris et al., 2005). A possible explanation could be that low kinesthetic imagers are more influenced by external aids to direct their general imagery experience. In fact, despite kinesthetic and visual imagery being different abilities, they are also correlated and part of the motor imagery construct. An alternative explanation would be that people high in kinesthetic ability immediately adopt the right perspective and either they keep it or it becomes slightly weaker, hence not presenting the shift. However, the adopted imagery perspective was not correlated to imagery ability, so it may just be that people high in kinesthetic imagery are less prone to shift perspective, regardless of whether the perspective is the one being instructed.

General Implications

The results of the present study carry a few theoretical implications with them. The fact that dynamic imagery did not show significant improvements across trials when compared to static imagery is distant from predictions of the PETTLEP model (Holmes & Collins, 2001) or any functional equivalence approach. According to these models, the afferent feedback that comes with movement should have strengthened the memory trace and hence made imagery more effective for participants who performed dynamic imagery. One thing that should be noted is that this study specifically singled out movement, which is only one part of the *physical* component of the PETTLEP model. In fact, both dynamic and motionless participants were wearing similar clothes and not holding a dart in their hands. Therefore, this study did not specifically address the difference between presence or absence of the physical component of PETTLEP. This phenomenon has already been explored in sports such as snow skiing (Callow, Roberts, & Fawkes, 2006). Similarly, it should be noted that Callow et al. (2006) did not find a difference in performance between physical and non-physical groups. However, they did find a significant difference between physical and control, something that the present study did not. That being said, the population of introductory psychology students from which the sample of the present study was drawn is very different from one of experienced athletes. Specifically, athletes have already experienced how the correct movements of their sport should feel like, something that may be necessary in order for dynamic imagery to be effective.

The findings of this study about perspective enrich the extensive literature on imagery perspective, showing that as far as aiming sports are concerned, one perspective does not seem to be more performance-enhancing than another. As a result, the claim that internal visual imagery should always be preferred due to its functional equivalence is weakened. That said, the PETTLEP model does recognize the possibility for External Visual Imagery to be more informative at times (Holmes & Collins, 2001), and since the theory is based on the information-processing function of motor imagery, adapting EVI would not necessarily go against this specific model.

Theoretical implications also arise with the findings about video condition. Particularly interesting is the improving trend of precision for those participants who saw the internal video. These participants saw a hand throwing like they would see theirs, but more importantly they saw the actor, a professional thrower, hitting the bull with all three darts. Despite all participants listened to an imagery script that was facilitative in nature (e.g., the imaginary dart hits the bullseye), those who watched the internal imagery video had a vivid visual memory of how hitting the bullseye looks like. Interesting implications arise for recent approaches trying to combine findings in action observation and motor imagery research. Vogt, Di Rienzo, Collet, Collins, and Guillot (2013) have made the point that both are underlined by a common process, namely motor simulation. Following this rationale, participants who watched the external video should have technically performed better since they watched the actor throwing (i.e., action) the dart, as opposed to the internal perspective video which did not show the actor’s body. However, as many athletes know, technical improvement does not immediately translate in improved performance or precision.

Accordingly, participants who watched the external video might have improved their dart-throwing technique more than those who watched the internal video, but not their performance or precision. Recently, Lawrence, Callow, and Roberts (2013) showed that the performance-enhancing role of action observation in a gymnastic task was mediated by imagery ability. However, it should be noted that gymnastic tasks have been shown to benefit more from external imagery (White & Hardy, 1995), so it could be that participants in Lawrence et al. (2013) improved their performance because they were exposed to the right kinds of visual aids. That said, the study by Lawrence et al. (2013) involved action rather than imagery interventions, so one needs to be careful in drawing conclusions.

Future Directions

The present study looked at some potentially important issues in motor imagery research, both from a research and an applied standpoint. For instance, the procedural choice of going through imagery training before each trial is something that has gained momentum in the literature (see Guillot et al., 2013), as opposed to just having imagery training between pre- and post-test trials. Continuing to explore this method can answer theoretical questions such as how long it takes for imagery to strengthen the relative memory traces. From an applied standpoint, looking at several imagery-physical practice trials can help us understand the right time and frequency of imagery practice for successful performance or technical improvements.

For what concerns imagery perspective, the fact that more people experienced an internal perspective can be seen as support for the default theory of imagery perspective (Morris & Spittle, 2001). Specifically, it seems to provide evidence that internal imagery is the natural and preferred perspective, regardless of visual imagery ability. One of the possible confounds here is that the videos showed a person other than the participant, a difference that was more highly noticeable in the external videos. In order to avoid this confound, participants could be recorded while throwing and shown a video of their best throws.

The findings about the video condition have high applied significance. To begin with, the fact that the video could predict shifts in imagery suggests that it has an influence on the visual aspect of motor imagery, especially because it provides an additional stimulus to enrich the specific memory trace (Holmes & Collins, 2001). Consequently, motor imagery training should implement videos from the desired perspective supporting the standard imagery scripts, especially if an athlete struggles to adopt the imagery perspective that works best for that specific sport. The fast-paced technological advancements in action sports camera could also serve athletes in imagery training, whether the desired perspective is internal or external. For instance, sports in which internal visual imagery perspective leads to improvements in performance, such as slalom-type sports (Callow et al., 2006; White & Hardy, 1995), could benefit from a point-of-view video. However, if one considers sports in which a specific imagery perspective is not more beneficial than another (e.g. aiming sports), the presence of both video perspectives, maybe through a split screen, could enhance the content of the memory trace.

To conclude, the vast amount of research and the widespread application of motor imagery techniques in applied settings stands as proof of the importance of motor imagery in athletics. Research aimed at understanding how visual contents and movements can improve the performance-enhancing qualities of motor imagery would allow athletes to be more efficient during practice, while helping them personalize the process. Many authors suggest shaping the imagery experience to conform to the specific athlete (Williams et al., 2013), and elite athletes continue to attest to the importance of the intimate and personal aspect of mental imagery in their profession. In the words of 1984 Olympic Winner Alex Baumann, "I see where everybody else is, and then I really focus on myself. . . . I think about my own race and nothing else. I am really swimming the race in my mind." (Olrick, 2000, p. 116)

References

Borst, G., Ganis, G., Thompson, W. L., & Kosslyn, S. M. (2011). Representations in mental imagery and working memory: Evidence from different types of visual masks. *Memory & Cognition*, *40*, 204–217. doi:10.3758/s13421-011-0143-7

Callow, N., Roberts, R., & Fawkes, J. Z. (2006). Effects of dynamic and static imagery on vividness of imagery, skiing performance, and confidence. *Journal of Imagery Research in Sport and Physical Activity*, *1*, 1–13.

Chu, M., & Kita, S. (2011). The nature of gestures' beneficial role in spatial problem solving. *Journal of Experimental Psychology: General*, *140*, 102–116. doi:10.1037/a0021790

Coelho, C. J., Nusbaum, H. C., Rosenbaum, D. A., & Fenn, K. M. (2012). Imagined actions aren't just weak actions: Task variability promotes skill learning in physical practice but not in mental practice. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*, 1759–1764. doi:10.1037/a0028065

Cumming, J. L., Nordin, S. M., Horton, R., & Reynolds, S. (2006). Examining the direction of imagery and self-talk on dart-throwing performance and self efficacy. *The Sport Psychologist*, *20*, 257–274.

Cumming, J. L., & Ste-Marie, D. M. (2001). The cognitive and motivational effects of imagery training: A matter of perspective. *The Sport Psychologist*, *15*, 276–288.

Driskell, J. E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance? *Journal of Applied Psychology*, *79*, 481–492.

Epstein, M. L. (1980). The relationship of mental imagery and mental rehearsal to performance of a motor task. *Journal of Sport Psychology*, *2*, 211–220.

Gordon, S., Weinberg, R., & Jackson, A. (1994). Effect of internal and external imagery on cricket performance. *Journal of Sport Behavior*, *17*, 60–75.

Gregg, M., Hall, C., & Butler, A. (2010). The MIQ-RS: A suitable option for examining movement imagery ability. *Evidence-Based Complementary and Alternative Medicine*, *7*, 249–257. doi:10.1177/0888439004265249

Gregg, M., Hall, C., & Nederhof, E. (2005). The imagery ability, imagery use, and performance relationship. *The Sport Psychologist*, *19*, 93–99.

Guillot, A., & Collet, C. (2008). Construction of the Motor Imagery Integrative Model in Sport: A review and theoretical investigation of motor imagery use. *International Review of Sport and Exercise Psychology*, *1*, 31–44. doi:10.1080/17509840701823139

Guillot, A., Moschberger, K., & Collet, C. (2013). Coupling movement with imagery as a new perspective for motor imagery practice. *Behavioral and Brain Functions*, *9*, 1–8. doi:10.1186/1744-9081-9-8

Hale, B. D. (1982). The effects of internal and external imagery on muscular and ocular concomitants. *Journal of Sport Psychology*, *4*, 379–387.

Hall, C. R., Mack, D. E., Paivio, A. A., & Hausenblas, H. A. (1998). Imagery use by athletes: Development of the sport imagery questionnaire. / Utilisation des representations mentales par les athletes: Developpement du questionnaire sur les representations mentales dans le sport. *International Journal Of Sport Psychology,* 29, 73-89.

Hall, C.R., & Martin, K.A. (1997). Measuring movement imagery abilities: A revision of the Movement Imagery Questionnaire. *Journal of Mental Imagery*, *21*, 143-154.

Hardy, L. (1997). The Coleman Robert Griffiths Address: Three myths about applied consultancy work. *Journal of Applied Sport Psychology*, *9*, 277–294.

Hardy, L., & Callow, N. (1999). Efficacy of external and internal visual imagery perspectives for the enhancement of performance on tasks in which form is important. *Journal of Sport & Exercise Psychology*, *21*, 95–112.

Hecker, J. E., & Kaczor, L. M. (1988). Application of imagery theory to sport psychology: Some preliminary findings. *Journal of Sport & Exercise Psychology*, *10*, 363–373.

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

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

Jackson, S., & Czikszentmihalyi, M. (1999). *Flow in sports: The keys to optimal experiences and performances*. Champaign, IL: Human Kinetics.

Jeannerod, M., & Decety, J. (1995). Mental motor imagery: A window into the representational stages of action. *Current Opinion in Neurobiology*, *5*, 727–732.

Kosslyn, S. M., Alpert, N. M., Thompson, W. L., Maljkovic, V., Weise, S. B., Chabris, C. F., . . . Buonanno, F. S. (1993). Visual mental imagery activates topographically organized visual cortex: PET investigations. *Journal of Cognitive Neuroscience*, *5*, 263–287. doi:10.1016/0042-6989(84)90041-5

Lawrence, G., Callow, N., & Roberts, R. (2013). Watch me if you can: Imagery ability moderates observational learning effectiveness. *Frontiers in Human Neuroscience*, *7*, 1–7. doi:10.3389/fnhum.2013.00522

Mahoney, M. J., & Avener, M. (1977). Psychology of the elite athlete: An exploratory study. *Cognitive Therapy and Research*, *1*, 135-141.

McLean, N., & Richardson, A. (1994). The role of imagery in perfecting already learned physical skills. In A. A. Sheikh & E. R. Korn (Eds.) *Imagery in sports and physical performance* (59-73). Amityville, NY: Baywood Publishing.

Morris, T., & Spittle, M. (2001). Internal and external imagery: A case of default theory? In A. Papaioannou, M. Goudas, & Y. Theodorakis (Eds.), *Proceedings of the X World Congress of Sport Psychology*. Athens, Greece: ISSP.

Morris, T., Spittle, M., & Watt, A. P. (2005). *Imagery in sport.* Champaign, IL: Human Kinetics.

Nordin, S. M., & Cumming, J. L. (2005). More than meets the eye: Investigating imagery type, direction, and outcome. *The Sport Psychologist*, *19*, 1–17.

Orlick, T. (2000). *In pursuit of excellence: How to win in sport and life through mental training*. (3rd Ed.). Champaign, IL: Human Kinetics.

Paivio, A. A. (1975). Coding distinctions and repetition effects in memory. In G. H. Bower (Ed.), *Psychology of learning and motivation* (*Vol. 9,* pp. 179-212). Orlando, FL: Academic Press.

Paivio, A. A. (1985). Cognitive and motivational functions of imagery in human performance. *Canadian Journal of Applied Sport Sciences. Journal Canadien Des Sciences Appliquées Au Sport, 10*, 22S–28S.

Pylyshyn, Z. W. (1992). Tacit knowledge and “mental scanning.” In B. Beakley & P. Ludlow (Eds.), *The philosophy of mind: Classical problem/contemporary issues* (pp. 229–239). Cambridge, MA: MIT Press.

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

Roberts, R., Callow, N., Hardy, L., Markland, D., & Bringer, J. (2008). Movement imagery ability: Development and assessment of a revised version of the Vividness of Movement Imagery Questionnaire. *Journal of Sport & Exercise Psychology*, *30*, 200–221.

Roberts, R., Callow, N., Hardy, L., Woodman, T., & Thomas, L. (2010). Interactive effects of different visual imagery perspectives and narcissism on motor performance. *Journal of Sport & Exercise Psychology*, *32*, 499–517.

Ryan, E. D., & Simons, J. (1981). Cognitive demand, imagery, and frequency of mental rehearsal as factors influencing acquisition of motor skills. *Journal of Sport Psychology*, *3*, 35–45.

Schuster, C., Hilfiker, R., Amft, O., Scheidhauer, A., Andrews, B., Butler, J … Ettlin, T. (2011). Best practice for motor imagery: A systematic literature review on motor imagery training elements in five different disciplines. *BMC Medicine*, *9*, 1-35. doi:10.1080/10413209608406306

Shepard, R. N., & Cooper, L. A. (1986). *Mental images and their transformation.* Cambridge, MA: MIT Press/Bradford Books.

Slade, J. M., Landers, D. M., & Martin, P. E. (2002). Muscular activity during real and imagined movements: A test of inflow explanations. *Journal of Sport & Exercise Psychology*, *24*, 151–167.

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

Smith, D., Wright, C., Allsopp, A., & Westhead, H. (2007). It's all in the mind: PETTLEP-based imagery and sports performance. *Journal of Applied Sport Psychology*, *19*, 80–92. doi:10.1080/10413200600944132

Spittle, M., & Morris, T. (2011). Can internal and external imagery perspectives be trained? *Journal of Mental Imagery*, *35*, 81–104.

Sutton, J. (2012). Memory before the game: Switching perspectives in imagining and remembering sport and movement. *Journal of Mental Imagery*, *38*, 85–95.

Tye, M. (1991). *The imagery debate.* Cambridge, MA: MIT Press/Bradford Books.

Ungerleider, S., & Golding, J. M. (1991). Mental practice among Olympic athletes. *Perceptual and Motor Skills*, *72*, 1007-1017.

Van Raalte, J. L., Brewer, B. W., Lewis, B. P., Linder, D. E., Wildman, G., & Kozimor, J. (1995). Cork: The effects of positive and negative self-talk on dart throwing performance. *Journal of Sport Behavior*, *18*, 50–57.

Vogt, S., Di Rienzo, F., Collet, C., Collins, A., & Guillot, A. (2013). Multiple roles of motor imagery during action observation. *Frontiers in Human Neuroscience*, *7*, 1–13. doi:10.3389/fnhum.2013.00807/abstract

White, A., & Hardy, L. (1995). Use of different imagery perspectives on the learning and performance of different motor skills. *British Journal of Psychology*, *86*, 169–180.

White, A., & Hardy, L. (1998). An in-depth analysis of the uses of imagery by high-level slalom canoeists and artistic gymnasts. *The Sport Psychologist*, *12*, 387–403.

Williams, S. E., Cooley, S. J., Newell, E., Weibull, F., & Cumming, J. L. (2013). Seeing the difference: Developing effective imagery scripts for athletes. *Journal of Sport Psychology in Action*, *4*, 109–121. doi:10.1080/21520704.2013.781560

Williams, S. E., & Cumming, J. L. (2012). Challenge vs. threat: Investigating the effect of using imagery to manipulate stress appraisal of a dart throwing task. *Sport & Exercise Psychology Review*, *8*, 4–21.

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

Wuyam, B., Moosavi, S. H., Decety, J., Adams, L., Lansing, R. W., & Guz, A. (1995). Imagination of dynamic exercise produced ventilatory responses which were more apparent in competitive sportsmen. *Journal of Physiology*, *3*, 713–724.

Ziegler, S. G. (1987). Comparison of imagery styles and past experience in skills performance. *Perceptual and Motor Skills*, *64*, 579–586.

Appendix A: Recurring Abbreviations

MI: Motor Imagery

MP: Mental Practice

CS: Cognitive Specific imagery

CG: Cognitive General imagery

MS: Motivational Specific imagery

MG-A: Motivational General-Arousal imagery

MG-M: Motivational General-Mastery imagery

IVI: Internal Visual Imagery

EVI: External Visual Imagery

VI: Visual Imagery

KI: Kinesthetic Imagery

Appendix B: Dartboard Design and Point Distribution

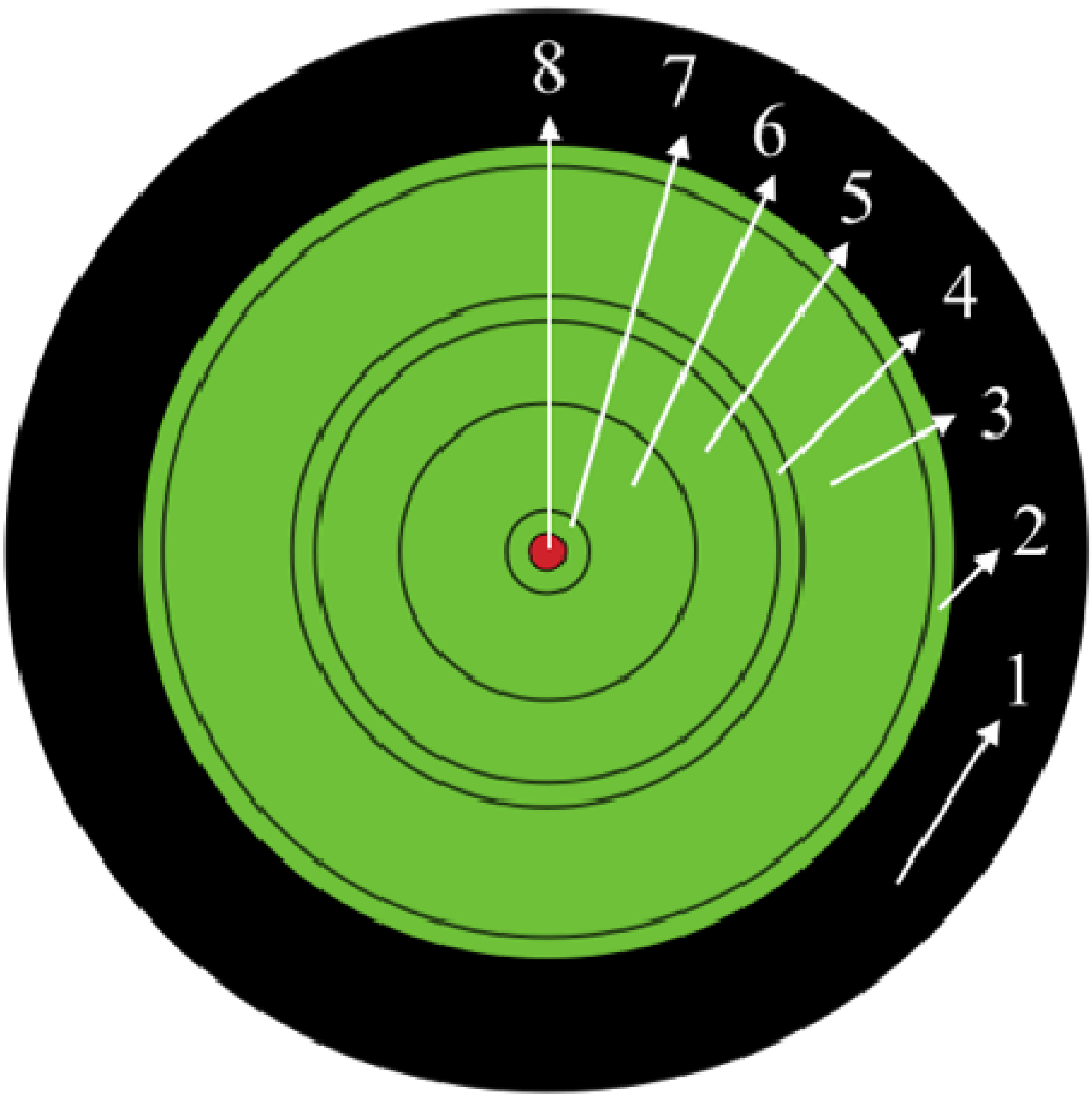

Figure B1. Dartboard design and scoring system.

Appendix C: Activity Questionnaire

Activity Questionnaire

Welcome to the Activity Questionnaire. The purpose of this questionnaire is to assess your ability on a variety of tasks, sports, and games.

1. What is your age?

2. What is your gender?
- Male
- Female

3. Are you left- or right-handed?
- Left-handed
- Right-handed

4. Please check the following table assessing how skilled you are at the following activities

	highly unskilled	very unskilled	somewhat unskilled	neither skilled nor unskilled	somewhat skilled	very skilled	highly skilled
snow skiing							
golf putting							
golf driving							
chess							
skeet shooting							
dart throwing							
bowling							
skateboarding							

Activity Questionnaire (continued)

5. Please check the following table assessing how often you perform the following activities

	more than once per week	once per week	once per month	once every three months	once per year	less than once per year
snow skiing						
golf putting						
golf driving						
chess						
skeet shooting						
dart throwing						
bowling						
skateboarding						

6. Please check the following table by choosing the last time you performed the following activities.

	last week	over a week ago	over a month ago	over three months ago	over six months ago	over a year ago
snow skiing						
golf putting						
golf driving						
chess						
skeet shooting						
dart throwing						
bowling						
skateboarding						

Activity Questionnaire (continued)

7. Please check the following table assessing how often you are exposed (e.g., TV, watching live events, listening to friends conversations) to the following activities

	more than once per week	once per week	once per month	once every three months	once per year	less than once per year
snow skiing						
golf putting						
golf driving						
chess						
skeet shooting						
dart throwing						
bowling						
skateboarding						

8. Please check the following table by choosing what your general interest is in the following activities.

	highly uninterested	very uninterested	somewhat uninterested	neither interested nor uninterested	somewhat interested	very interested	highly interested
snow skiing							
golf putting							
golf driving							
chess							
skeet shooting							
dart throwing							
bowling							
skateboarding							

Appendix D: Manipulation Check Questionnaire

Questionnaire 2

Please circle the answer that applies

1. Did you use imagery in the way it was instructed to you by the experimenter?

not at all	somewhat	yes	yes, in every part

2. Did you follow the imagery steps presented to you through the audio script?

not at all	somewhat	yes	yes, in every part

3. Did you always aim at the bullseye?

not at all	somewhat	yes	yes, in every part

4. With 0 being "completely inside" and 10 being "completely outside", during the imagery trials, did you see yourself from an outside view (i.e., as if you were watching yourself on video) or from an inside view (i.e., as if you were actually inside yourself)?

0	1	2	3	4	5	6	7	8	9	10

5. With 1 being "completely unhelpful" and 5 being "completely helpful", what did you feel the role of the imagery trials to be?

1	2	3	4	5

Appendix E: Post-Experiment Manipulation Check Questionnaire for Imagery Groups

Questionnaire 3

Please circle the answer that applies

1. Did you use imagery in the way it was instructed to you by the experimenter?

not at all	somewhat	yes	yes, in every part

2. Did you follow the imagery steps presented to you through the audio script?

not at all	somewhat	yes	yes, in every part

3. Did you always aim at the bullseye?

not at all	somewhat	yes	yes, in every part

4. With 0 being "completely inside" and 10 being "completely outside", during the imagery trials, did you see yourself from an outside view (i.e., as if you were watching yourself on video) or from an inside view (i.e., as if you were actually inside yourself)?

0	1	2	3	4	5	6	7	8	9	10

5. How similar to the point of view of the video was your perspective <u>in the early stages</u> of the experiment?

1	2	3	4	5	6	7
Very different	Different	Somewhat different	Neutral (not different nor similar)	Somewhat similar	Similar	Very similar

Post-Experiment Manipulation Check Questionnaire for imagery groups (continued)

6. How similar to the point of view of the video was your perspective <u>in the final stages</u> of the experiment?

1	2	3	4	5	6	7
Very different	Different	Somewhat different	Neutral (not different nor similar)	Somewhat similar	Similar	Very similar

7. Did you find yourself switching between internal and external perspectives <u>in the early stages</u> of the experiment?

never	rarely	sometimes	often	all the time

8. Did you find yourself switching between internal and external perspectives <u>in the final stages</u> of the experiment?

never	rarely	sometimes	often	all the time

9. With 1 being "completely unhelpful" and 5 being "completely helpful", what did you feel the role of the imagery trials to be?

1	2	3	4	5

10. Did you find yourself using other strategies while throwing darts? Circle all that applies

positive self-talk	negative self-talk	goal setting	other
none			

Post-Experiment Manipulation Check Questionnaire for imagery groups (continued)

11. If you circled "other" on question 10, could you please tell us what kind of strategy you found yourself using? This information will be very valuable for future research.

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Appendix F: Post-Experiment Manipulation Check Questionnaire for Control Group

Questionnaire 2

Please circle the answer that applies

1. Did you always aim at the bullseye?

not at all	somewhat	yes	yes, in every part

2. Did you find yourself using other strategies while throwing darts? Circle all that applies

positive self-talk	negative self-talk	goal setting	visual imagery
other	none		

3. If you circled "other" on question 4, could you please tell us what kind of strategy you found yourself using? This information will be very valuable for future research.

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Appendix G: Movement Imagery Questionnaire 3

Full Questionnaire with Instructions

<u>Instructions</u>

This questionnaire concerns two ways of *mentally* performing movements which are used by some people more than by others, and are more applicable to some types of movements than others. The first is attempting to form a visual image or picture of a movement in your mind. The second is attempting to feel what performing a movement is like without actually doing the movement. You are requested to do both of these mental tasks for a variety of movements in this questionnaire, and then rate how easy/difficult you found the tasks to be. The ratings that you give are not designed to assess the goodness or badness of the way you perform these mental tasks. They are attempts to discover the capacity individuals show for performing these tasks for different movements. There are no right or wrong ratings or some ratings that are better than others.

Each of the following statements describes a particular action or movement. Read each statement carefully and then actually perform the movement as described. Only perform the movement a single time. Return to the starting position for the movement just as if you were going to perform the action a second time. Then depending on which of the following you are asked to do, either (1) form as clear and vivid a visual image as possible of the movement just performed from an internal perspective (i.e., from a 1st person perspective, as if you are actually inside yourself performing and seeing the action through your own eyes), (2) form as clear and vivid a visual image as possible of the movement just performed from an external perspective (i.e., from a 3rd person perspective, as if watching yourself on DVD), or (3) attempt to feel yourself making the movement just performed without actually doing it.

After you have completed the mental task required, rate the ease/difficulty with which you were able to do the task. Take your rating from the following scale. Be as accurate as possible and take as long as you feel necessary to arrive at the proper rating for each movement. You may choose the same rating for any number of movements "seen" or "felt" and it is not necessary to utilize the entire length of the scale.

RATING SCALES

Visual Imagery Scale

1	2	3	4	5	6	7
Very hard to see	Hard to see	Somewhat hard to see	Neutral (not easy nor hard)	Somewhat easy to see	easy to see	Very easy to see

Kinesthetic Imagery Scale

1	2	3	4	5	6	7
Very hard to feel	Hard to feel	Somewhat hard to feel	Neutral (not easy nor hard)	Somewhat easy to feel	easy to feel	Very easy to feel

Movement Imagery Questionnaire 3 (continued)

1. STARTING POSITION: Stand with your feet and legs together and your arms at your sides.

ACTION: Raise your right knee as high as possible so that you are starting on your left leg with your right leg flexed (bent) at the knee. Now lower your right leg so you are once again standing on two feet. The action is performed **slowly**.

MENTAL TASK: Assume the starting position. Attempt to **feel** yourself making the movement just observed without actually doing it. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: __________

2. STARTING POSITION: Stand with your feet and legs together and your arms at your sides.

ACTION: Bend down low and then jump straight up in the air as high as possible with both arms extended above your head. Land with both feet apart and lower your arms to your sides.

MENTAL TASK: Assume the starting position. Attempt to **see** yourself making the movement just observed from an **internal perspective**. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: __________

3. STARTING POSITION: Extend the arm of your non-dominant hand straight out to your side so that it is parallel to the ground, palm down.

ACTION: Move your arm forward until it is directly in front of your body (still parallel to the ground). Keep your arm extended during the movement, and make the movement **slowly**.

MENTAL TASK: Assume the starting position. Attempt to **see** yourself making the movement just observed from an **external perspective**. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: __________

Movement Imagery Questionnaire 3 (continued)

4. STARTING POSITION: Stand with your feet slightly apart and your arms fully extended above your head.

ACTION: **Slowly** bend forward at the waist and try and touch your toes with your fingertips (or, if possible, touch the floor with your fingertips or your hands). Now return to the starting position, standing erect with your arms extended above your head.

MENTAL TASK: Assume the starting position. Attempt to **feel** yourself making the movement just observed without actually doing it. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: ___________

5. STARTING POSITION: Stand with your feet and legs together and your arms at your sides.

ACTION: Raise your right knee as high as possible so that you are starting on your left leg with your right leg flexed (bent) at the knee. Now lower your right leg so you are once again standing on two feet. The action is performed **slowly**.

MENTAL TASK: Assume the starting position. Attempt to **see** yourself making the movement just observed from an **internal perspective**. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: ___________

6. STARTING POSITION: Stand with your feet and legs together and your arms at your sides.

ACTION: Bend down low and then jump straight up in the air as high as possible with both arms extended above your head. Land with both feet apart and lower your arms to your sides.

MENTAL TASK: Assume the starting position. Attempt to **see** yourself making the movement just observed from **an external perspective**. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: ___________

Movement Imagery Questionnaire 3 (continued)

7. STARTING POSITION: Extend the arm of your non-dominant hand straight out to your side so that it is parallel to the ground, palm down.

ACTION: Move your arm forward until it is directly in front of your body (still parallel to the ground). Keep your arm extended during the movement, and make the movement **slowly**.

MENTAL TASK: Assume the starting position. Attempt to **feel** yourself making the movement just performed without actually doing it. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: ___________

8. STARTING POSITION: Stand with your feet slightly apart and your arms fully extended above your head.

ACTION: **Slowly** bend forward at the waist and try and touch your toes with your fingertips (or, if possible, touch the floor with your fingertips or your hands). Now return to the starting position, standing erect with your arms extended above your head.

MENTAL TASK: Assume the starting position. Attempt to **see** yourself making the movement just observed from an **internal perspective**. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: ___________

9. STARTING POSITION: Stand with your feet and legs together and your arms at your sides.

ACTION: Raise your right knee as high as possible so that you are starting on your left leg with your right leg flexed (bent) at the knee. Now lower your right leg so you are once again standing on two feet. The action is performed **slowly**.

MENTAL TASK: Assume the starting position. Attempt to **see** yourself making the movement just observed from **an external perspective**. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: ___________

Movement Imagery Questionnaire 3 (continued)

10. STARTING POSITION: Stand with your feet and legs together and your arms at your sides.

ACTION: Bend down low and then jump straight up in the air as high as possible with both arms extended above your head. Land with both feet apart and lower your arms to your sides.

MENTAL TASK: Assume the starting position. Attempt to **feel** yourself making the movement just performed without actually doing it. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: ___________

11. STARTING POSITION: Extend the arm of your non-dominant hand straight out to your side so that it is parallel to the ground, palm down.

ACTION: Move your arm forward until it is directly in front of your body (still parallel to the ground). Keep your arm extended during the movement, and make the movement **slowly**.

MENTAL TASK: Assume the starting position. Attempt to **see** yourself making the movement just observed from an **internal perspective**. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: ___________

12. STARTING POSITION: Stand with your feet slightly apart and your arms fully extended above your head.

ACTION: **Slowly** bend forward at the waist and try and touch your toes with your fingertips (or, if possible, touch the floor with your fingertips or your hands). Now return to the starting position, standing erect with your arms extended above your head.

MENTAL TASK: Assume the starting position. Attempt to **see** yourself making the movement just observed from an **external perspective**. Now rate the ease/difficulty with which you were able to do this mental task.

Rating: ___________

Appendix H: Audio Instructions for Videos

Hello, and thank you for participating in this imagery experiment. Today, Tracy will show you the right technique to use when throwing a dart.

First of all, make sure that you position yourself behind the line with your feet apart. If you are right-handed, your right foot should be touching the line. If you are left-handed, your left foot should be the one touching the line. As you look at the dartboard, make sure your weight is primarily distributed on your front foot.

Your upper body should be upright and your shoulders relaxed. Find a comfortable grip of the dart, making sure you are gripping the dart with at least three fingers.

Bring your upper arm to a 90 degrees angle from your torso. Align the dart to the bullseye and feel your wrist firm and in control. Start aiming at the bullseye by looking at your dart. Slowly move your forearm back towards you, and then throw the dart towards the board. As you throw, make sure that your shoulder does not move. Follow through the throw with your forearm.

As you can see from Tracy's throws, the dart follows a parabolic trajectory, so keep that in mind as you throw.

Appendix I: Audio Instructions for Non-Imagery Group

Here are the technical details that you should be focusing on while throwing darts:

- Make sure to stand with your feet apart, and your weight distributed more on your dominant leg. So, if you are right handed, your right foot should be forward; the outside of your right foot should be touching the line; and your weight should be distributed more on your right leg.
- Make sure to be in a perfect position through an upright upper body and relaxed shoulders.
- Make sure your head is straight and looking at the center of the dartboard. While holding the dart in your hand with a firm grip, picture the parabolic trajectory that your dart will follow to the bullseye.
- Make sure to bring the dart back towards you in a slow and smooth fashion before throwing. As you do this, keep your eyes and focus on the bullseye
- As you throw, make sure that your forearm and wrist lead the execution. Your shoulder may move, but it should not be involved in the throwing motion. Follow through with your hand as you release the dart in order to maintain one whole, smooth movement.

Appendix J: Audio Script for Imagery Groups

Please walk towards the line and assume the stance that you practiced. Stand with your feet apart, your weight mainly on your front leg. Look at your feet; see that they are slightly apart, that the outside of your front foot is against the line.

Feel yourself in a perfect position. Feel that your upper body is upright and that your shoulders are relaxed. Feel your throwing arm bent towards your shoulder. Feel the firm grip of your throwing hand around the dart.

The image should be you, standing slightly sideways on, perfectly lined up with the dart resting in your hand. Your head is up and looking forward. Now find the imaginary trajectory that the dart will follow straight to the bullseye. This parabolic line is the one in which you are going to throw the dart. Now feel yourself pointing with the dart at the board's center, then bringing the dart back, bringing your arm back smoothly. Feel your hand and forearm acting as a single unit and your wrist is held firm and strong.

The dart feels light. Feel your head and shoulders staying up and motionless with your eyes totally concentrated on the bullseye. Feel your smooth and consistent movement from bent to almost straight arm. Your body stays still and relaxed, with only your arm moving.

Feel your hand beginning to move in a straight line to form a perfect trajectory toward the very center of the dartboard. Follow through the throw with your forearm. Feel yourself finish the throw: smoothly, effortlessly, a straight and consistent throw. See the point of release when the hand lets go of the dart, just at the right time.

See the perfectly smooth, parabolic trajectory of the dart flying through the air. It is looking very promising. Watch it approach the dartboard. Follow it all the way, your perfect throw making it land straight in the center of the board, right in the bullseye.

Appendix K: Unadjusted Means of Performance and Precision

Note: EVI stands for External Visual Imagery; IVI for Internal Visual Imagery; NM for Non-Movement; and M for Movement.

Table K1

Unadjusted Means of Performance for the 5 Experimental Groups

	Assessment	Trial 1	Trial 2	Trial 3	Trial 4
EVI, M	3.94166667	3.80416667	4.1875	4.4625	4.2625
EVI, NM	4.10416667	4.49166667	4.53333333	4.56666667	4.48333333
IVI, M	4.3625	4.35	4.7	4.50833333	4.75833333
IVI, NM	4.17916667	4.3625	4.42916667	4.55416667	4.58333333
Control	3.70416667	3.98333333	4.05416667	4.25416667	4.02916667

Table K2

Unadjusted Means of Precision for the 5 Experimental Groups

	Assessment	Trial 1	Trial 2	Trial 3	Trial 4
EVI, M	1.81874946	1.7886607	1.76024765	1.57673661	1.58536839
EVI, NM	1.66179623	1.5246563	1.34928284	1.38678746	1.58306785
IVI, M	1.62923369	1.59839197	1.43946259	1.45179861	1.29316297
IVI, NM	1.70926438	1.69228005	1.41796997	1.51517196	1.36658504
Control	1.76855273	1.63264685	1.52562627	1.55855403	1.7135007

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ABSTRACT

The superior performance-enhancing features of dynamic imagery over static imagery have been defended by current motor imagery theories, especially those stressing functional equivalence. However, a substantial lack of applied research on the role of movement in motor imagery leaves this claim without the necessary support. On the other hand, the visual perspective of motor imagery has received a lot of attention, and several theories emerged addressing the conditions in which internal or external visual imagery should be employed. Among other issues, this study addressed the question of whether moving while imagining leads to increased performance enhancement. Also, differences in performance enhancement due to perspective were investigated.

Eighty introductory psychology students were randomly assigned to a movement and a perspective condition, leading to four experimental groups and a fifth control group that received no imagery training. A dart-throwing task was used to investigate performance enhancements over four trials. Videos from different points of view were used as the sole perspective-inducing method, while imagery training was aided by audio scripts presented before each dart-throwing trial. Results showed a nonsignificant perspective main effect in the way in which participants improved across trials. This finding is in line with previous research using a dart-throwing task. However, contrary to prediction, this study did not find a significant movement main effect. However, the video proved to be an effective perspective-

inducing method. The applied implications of these findings are discussed, as are future research directions.

Biographical Sketch

Matteo Luzzeri grew up in north Italy with his parents, Fedele and Eliana, and his wonderful sister Michela. He graduated with a Bachelor of Science in Psychology from the University of Louisiana at Lafayette and earned a Master of Science in Experimental Psychology at the same university. He will soon be working toward a Doctorate in Sport Psychology at Florida State University, after which he hopes to help individual athletes and teams to perform to their full potential.

Matteo has been combining his academic endeavors with a career in competitive water skiing. He represented the University of Louisiana at Lafayette with the Ragin' Cajun Water Ski Team during his undergraduate years. At the present time, he represents Italy at titled tournaments while also being part of the World Professional Tour. His hope is to continue the challenging and exciting life committed to both the lake and academia.