Handbook of Embodied Cognition and Sport Psychology

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23 Imagery, Expertise, and Action: A Window into Embodiment

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1 Introduction

In 1890 William James discussed the "idea that sensations modify the nervous system, and enable mental reproductions to emerge in the mind" (Park and Kosslyn 1990, 183). Furthermore, he categorized people on the basis of individual differences in their modality-specific imagery ability (e.g., visual and motor types). In 1990, Park and Kosslyn duly described how William James (1890) had been prescient in his synthesis of the key challenges in mental imagery research a century earlier. They asserted that his ideas on "the sensory-perceptual aspects of the mind have largely been neglected" (Park and Kosslyn, 1990, 183). Now, a quarter of a century after Park and Kosslyn's remarks, we have witnessed not only the proliferation of motor imagery research (Gabbard 2013; Glover and Baran 2017; Madan and Singhal 2012a; Moran et al. 2012) but also the emergence of embodied cognition approaches in the past two decades (Glenberg 2015; Loeffler, Raab, and Cañal-Bruland 2016; Wilson and Golonka 2013; Wilson 2002). This latter paradigm shift is at the forefront of cognitive science, as demonstrated by the surge in related research topics (Borghi and Pecher 2011; Lynott, Connell, and Holler 2013) and handbooks (e.g., Calvo and Gomila 2008; Shapiro 2011) and the emergence of a variety of approaches to the embodied cognition approach (Wilson 2002).

In this chapter, we explore the aforementioned paradigm shifts and how they offer an avenue for new research. We first elucidate what precisely "mental imagery," the parent construct of motor imagery, is and explain the research milestones that have elucidated our understanding of this complex topic. The construct of motor imagery has become a thriving research topic thanks to the development of the action simulation model by Marc Jeannerod, which provided a framework in which imagery and movement are viewed as part of an action continuum (Jeannerod 1994, 2006).

Three key pivots occurred over two decades of motor imagery research, relating to conceptual issues, measurement challenges, and the application of the expertise

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paradigm; each is explained in turn. Subsequently, the potential for grounded cognition accounts to explain the interactions among our cognition, action, and emotional systems is evaluated (Shapiro 2011). The grounded cognition approach to investigating motor imagery arguably provides an opportunity for the interdisciplinary investigation of questions on the nature of representation with implications for researchers and practitioners alike. Finally, new directions for both scientists and practitioners are addressed, with the emphasis on athletic samples, including those suffering from sport injury. First, we consider the construct of mental imagery and its link to expertise and skill acquisition.

William James (1890) wrote how your imagination could allow you *learn to swim* in winter and *learn to skate* in summer. This application of imagery, as we shall see later in this chapter, is known as *mental practice*, and while understanding the utility of imagery as a simulation process was central to scientific interest since James's first musings, mental imagery and its motor equivalent are also of interest for theoretical reasons. For example, research on visual imagery has elucidated our understanding of visual perception (Kosslyn, Thompson, and Ganis 2006). Similarly, findings from motor imagery (the simulation of action) have enhanced our knowledge of action-control mechanisms in both healthy and pathological brains (de Lange, Roelofs, and Toni 2008). Understanding action is important because, historically, it has been a neglected topic in psychological science (Rosenbaum 2005). Among the reasons for its neglect is the "dumb-jock hypothesis," which, according to Rosenbaum, (2005) suggests that "one does not have to be highly intelligent, as measured by IQ tests, to move well" (311). The work of Bartlett (1932) on motor schema provided a welcome exploration from cognitive perspective on action concepts (Moran 2012). However, this was an exception among psychology researchers who had largely been "preoccupied with disembodied perceptions … and indifferently concerned with translating perceptions and higher processes into action" (Adams 1987, 66).

Inspired by the ecological approach of Gibson (1979), the development of direct-perception explanations for action spawned an alternative theoretical account. These approaches were no longer dominated by a concern with the internal representations and computations underlying action prevalent in disembodied perspectives (e.g., Newell and Simon 1972) that had led to the exclusion of embodied cognition approaches previously.

Embodied cognition is the idea that cognitive representations are "grounded in, and simulated through, sensorimotor activity" (Slepian et al. 2011, 26) or that mental processes that evolved to control action can also be used off-line to simulate motor skills and knowledge (Wilson 2002). It has been described as a "multifaceted theoretical proposition that (1) cognitive processes are influenced by the body, (2) cognition exists in the service of action, (3) cognition is situated in the environment, and (4) cognition may occur without internal representation" (Goldinger et al. 2016, 959). To explain, Lorey et al. (2009) proposed that body-related experiences also shape processes such as imagery formerly conceptualized as purely "cognitive" or disembodied. Conflicting evidence has led to researchers varying in the degree to which their explanations are in fact embodied. These range from grounded cognition to enactivism, and conflicting evidence has emerged that has been discussed in preceding chapters. Emerging accounts of grounded cognition outline how sensation, motor activity, and perceptual imagery shape cognitive processes ranging from object representation to emotion recognition (Slepian et al. 2011).

Research on aspects of embodied cognition in sport has been one impetus for the return of action research to the realm of interdisciplinary scientific discovery. Philosophers (Cappuccio 2015) and neuroscientists concerned with action (Beilock 2008), language (Bergen 2012), and concepts (Barsalou 2008) have all looked to sport to explain the implications of embodied cognition approaches (see also Shapiro and Spaulding, this volume).

2 What Is Mental Imagery?

To illuminate how motor imagery offers a window into embodied cognition, it is necessary to revisit how mental imagery, the overarching construct, has been operationalized. Our capacity to reexperience scenarios or events that we've encountered previously is remarkable, perhaps superseded only by our ability to "experience objects or events that do not exist in the world through our imagination" (Pearson and Kosslyn 2013, 5). According to Pearson and Kosslyn, this ability is critical to our capacity to reanalyze our past, plan our future goals and actions, and even simulate events that may never occur.

Mental imagery has been operationalized in a myriad of ways since William James's chapters on imagination were written (1890). The diverse definitions of mental imagery to date reflect both the dominant paradigm of the time and the orientation of the researchers involved (i.e., whether experimental or applied in focus). For example, cognitive scientists have proposed that mental imagery can be defined as the cognitive simulation process by which we can represent perceptual information in our minds in the absence of appropriate sensory input (Munzert, Lorey, and Zentgraf 2009). An array of terms have been employed to explain the application of mental imagery, including *visualization, mental rehearsal, symbolic rehearsal, covert rehearsal, mental practice,* *visuo-motor behavior rehearsal (VMBR),* and *motor imagery* (see Moran et al. 2012). To explain, one of the earliest studies was conducted by Vandell et al. (1943), in which they explored the efficacy of mental practice in enhancing free-throw performance. Mental practice is "the systematic use of mental imagery to rehearse an action in the minds' eye without engaging the actual physical movements involved" (Moran 2012, 349), and it has been shown to be an effective performance-enhancement strategy, according to meta-analytic reviews with sport samples (Driskell, Copper, and Moran 1994) and randomized controlled trials with surgeons (Arora et al. 2011). Similarly, VMBR was developed by Richard Suinn (1972) and describes a procedure that combines relaxation and mental practice (Suinn 1997). From this we can conclude that mental imagery is a covert process, but it has been used to encompass a range of cognitive and behavioral processes including relaxation. Consequently, the operationalization of the term is challenging for researchers.

Not surprisingly, researchers have noted that "there continues to be no consensus on the definitions of imagery" (Schack et al. 2014, 5). Schack et al. (2014) explained that "imagery refers to a collection of abilities, including, for example, visual imagery, kinesthetic imagery, imagery of movements or combinations of imagery modalities" (5). This multisensory approach is supported by a long line of mental imagery research (Betts 1909; Belardinelli et al. 2004, 2009; Madan and Singhal 2012a; Sheehan et al. 1967). Sport psychologists have focused on the potential multisensory nature of the imagery experience and have defined it as "a symbolic sensory experience that may occur in any sensory mode" (Hardy, Jones, and Gould 1996, 28). This contrasts with the emphasis on imagery as a representation by cognitive scientists. For instance, Wraga and Kosslyn (2002) describe it as "an internal representation that gives rise to the experience of perception in the absence of the appropriate sensory input" (466).

The above dichotomy, whether imagery is conceptualized as a *quasi-perceptual phenomenological experience* or as a *mental representation*, was central to it becoming a legitimate area of study in the zeitgeist (Cornoldi and De Beni 2012). The complex and ephemeral nature of phenomenological accounts of imagery led to imagery being a neglected topic of study during the era of behaviorism. Even within the cognitive revolution, the topic generated a controversy that became known as the imagery debate (see Pylyshyn 2002). While the focus of the neuroscience research conducted by Stephen Kosslyn and other proponents of the analogical account of imagery was on the nature of the representation underlying visual imagery experiences (Kosslyn, Thompson, and Ganis 2006), motor imagery was also central to the illumination of the construct. This latter concern with action and imagery opened a window for the exploration of embodied cognition perspectives. Before we address the embodied nature of these representations, it is worthwhile to ascertain what precisely we mean by the term *motor imagery* and to evaluate whether there is agreement among researchers with regard to operational definitions of the term.

2.1 What Is Motor Imagery?

William James neatly summed up the embodied complexity of motor imagery when he wrote that “every representation of a movement awakens in some degree the actual movement” (1890, 526). Consequently, one can infer that, within the mental imagery construct, “motor imagery” refers to the mental representation of an action without engaging in its actual execution (Madan and Singhal 2012b; Moran et al. 2012). Again, we are confronted with a disembodied account of motor imagery. And the entropy only increases, as motor imagery typically occurs in conjunction with visual imagery, for example, rather than in isolation. On the other hand, visual imagery is commonly reported without other senses (Kosslyn et al. 1990). The interaction between visual and motor imagery only blurs the conceptual clarity further.

2.2 Is Motor Imagery *Limited* by Visual Imagery Perspective?

The dual visual viewpoint that one can adopt during imagery (whether first- or third-person) led to findings in which it was assumed that motor imagery was limited to an egocentric or first-person viewpoint (see Moran et al. 2012). This artifact, in which visual perspective during imagery was conflated with the presence or absence of motor imagery, created further confusion among researchers. Moran et al. (2012) refer to this issue as the “limited perspective problem.” Only recently have researchers reconciled this issue, as both neuroscience evidence (Fourkas, Ionta, and Aglioti 2006) and phenomenological studies with elite performers has confirmed the possibility of motor imagery from a third-person perspective or allocentric viewpoint (Callow and Roberts 2010; Moran and MacIntyre 1998).

Thus the definitional dilemma erroneously linked to visual perspective has been averted to some degree (Moran et al. 2012). A recent definition provides further clarity by specifying that motor imagery is a dynamic mental state during which the representation of a given motor act or movement is rehearsed in working memory without any overt motor output (Guillot and Collet 2010). The term *overt motor output* is used to highlight that it’s not the absence of movement per se but the activation at the muscular level that should be absent. For example, gripping a basketball in your hand while standing on the free-throw line will entail a degree of motor activation (e.g., postural activation, isometric force to grip the ball, and so on) even without any *overt movement*. One may expect that this increased level of conceptual clarity provides a solution for researchers and practitioners alike. However, William James wasn't wrong when he suggested that mental imagery of movement *awakens* to some extent the *actual movement*. This *contamination* of a cognitive simulation technique by motor processes, as we discuss later, has been termed *quasi-movements* by Nikulin et al. (2008) and is central to the argument in this paper that motor imagery is a construct highly relevant in advancing our accounts of grounded cognition.

3 Movement in Measurement Research

Since William James's early treatise, in which he discussed the nature of individual differences in imagery (1890), the topic of mental imagery had been hampered in its quest for legitimacy until an innovation in imagery measurement by Shepard and Metzler (1971). They devised the mental rotation paradigm, which was an implicit objective measure of what had been previously viewed only as a subjective experience impenetrable to rigorous measurement. Briefly, mental rotation involves the comparison of two 3-D block figure objects, which are presented in different orientations. To compare whether the two objects match, it was hypothesized that participants would *mentally rotate* one object to see if matched the criterion object. Response times increased linearly with increased differences in angular disparity. In other words, a second-order isomorphism existed, in that physical properties of objects influenced our operations on them in our mental world. Interestingly, "kinesthetic" sensations appeared to be present during mental rotation for some subjects, according to Jackie Metzler (coauthor with Roger Shepard, 1971). So visual imagery investigations were recognized as potentially involving the *motor* system. Kosslyn and Sussman later argued that "visual mental images are transformed in part via motor processes" (1995, 345). If this were the case, it would have implications for studies that were concerned with the localization of mental rotation processes at a neural level.

One question that emerged was whether the involvement of motor processes in mental rotation was due to a voluntary strategy adopted by participants. A subsequent neural study employed positron emission tomography (PET) while subjects mentally rotated either their hands or the original 3-D block objects (Kosslyn et al. 1998; also see Ganis et al. 2000). The results highlighted that two mechanisms could be applied: "one mechanism that recruits processes that prepare motor movements and another that does not" (Kosslyn et al. 1998, 151; also see Madan and Singhal 2012a). Was this a case of embodied cognition? Again we turn to a mental rotation study comparing animate versus inanimate stimuli for answers. Kosslyn et al. (2001) had subjects engage in a familiarization training condition prior to the mental rotation experiment. Participants viewed a 3-D block object being moved by an electric motor (exogenous force) or, in the alternative condition, were required to twist the object with their right hand to orient it (endogenous force).

The familiarization process influenced the strategy adopted by participants in the study, and only in the latter condition (endogenous force) was the primary motor cortex activated. Recent studies have also examined mental rotation of human figures, with results indicating an effect of embodiment (Madan and Singhal 2012c, 2014, 2015). These finding provided tentative evidence for grounded cognition in action simulation, a conclusion that became stronger as further empirical evidence to demonstrate that motor imagery was grounded in the physical experiences of the imager accumulated. The theoretical backdrop to these findings is now discussed in advance of the evaluation of the recent empirical evidence.

3.1 From Ideomotor Theory to Motor Cognition

William James had expounded on *ideomotor* theory, which he remarked "combined the driving force of a dominant idea with the resulting involuntary motor activity" (1890). This concept resonates clearly with the thrust of the current theoretical accounts from simulation theory. In the past two decades, a new domain of study called "motor cognition" has emerged (Jeannerod 1994, 2006). This field of study explores how the mind plans, simulates, and produces goal-directed movements. Specifically, it is concerned with the "preparation and production of actions as well as the processes involved in recognizing, anticipating, predicting and interpreting the actions of others" (Jackson and Decety 2004, 259).

An important distinction is made between the terms *movement* and *action*. "Action" is posited to have both covert stages (action simulation including motor imagery) and overt stages (movement execution), and movement related to when the activation leads to the displacement of a limb in space (i.e., proximal or distal). Within this approach, motor imagery is predicted to be functionally equivalent to action because it has been shown to share common neurological mechanisms, and information is processed in comparable ways. The discovery of mirror neurons stimulated research on the neural basis of action representations (Rizzolatti, Fogassi, and Gallese 2001).

According to Jeannerod (2006), the action continuum predicts that the difference between the simulation of an action and its executed counterpart is one of degree and not one of kind. Consequently, the continuum posits that at one end of the spectrum is an action representation and at the other end is intentional movement. This conceptualization, although not without criticism (Gallese and Sinigaglia 2011; Glover and Baran 2017) is of particular interest from an embodied cognition perspective, and it has implications for psychological science and applied psychology.

3.2 Is Motor Imagery Uncoupled from Action?

The motor cognition paradigm undoubtedly returns the study of action to psychology (Moran et al. 2012; MacIntyre et al. 2013). In addition, the motor cognition account questions the artificial decoupling of motor imagery from movement by providing an action spectrum encompassing imagery and motor execution. Traditionally, imagery, by definition, occurred in the absence of movement. Empirical evidence and practice-based evidence have questioned this decoupling. For example, at least one contemporary model of imagery in athletes postulates that movement *is* possible during imagined action (Holmes and Collins 2001). We now focus our attention on this issue.

Morris, Spittle, and Watt (2005), in their monograph on the topic of imagery in sport, state that imagery "may be considered as the creation or re-creation of an experience generated from memorial information, involving quasi-sensorial, quasi-perceptual and quasi-affective characteristics, that is under the volitional control of the imager, and which *may* occur in the absence of the real stimulus antecedents normally associated with the actual experience" (19, emphasis added). This definition retains key elements of traditional definitions (e.g., multisensory, conscious experience) but is novel in that it includes the possibility that imagery and action may co-occur.

The traditional definitions of mental imagery presuppose that the simulation occurs in the absence of actual perception or movement execution. However, as we discovered with motor imagery in mental rotation, the complexity of these processes means they are not easily dissociable. In the visual imagery literature, for example, it has been suggested that there is no such thing as immaculate perception (Kosslyn and Sussman 1995). Thus, visual imagery was seen to be central to perception in providing top-down knowledge that influenced our visual recognition abilities. Indeed, early studies by Perky (1910) attempted to answer the question of the role of imagery in perceptual recognition by projecting a faint illustration of objects during imagery of either congruent or incongruent objects. While debate over the methods continues, the principle that imagery can facilitate visual recognition processes remains.

In the motor context, *quasi-movements*—a term used by Nikulin et al. (2008) to describe volitional movements that are suppressed during motor imagery and thus are neither movement execution nor motor imagery per se—have been recorded. The inhibition of such movements is integral to motor imagery processes (Guillot et al. 2012), and these movements are described as part of what has been termed *dynamic* *imagery* (MacIntyre and Moran 2010). Again, by definition, motor imagery is said to occur in the absence of any overt movement or motor output (Guillot and Collet 2010). However, on the basis that athletes often engage in movements while engaging in imagery, sport psychologists have recommended that performers apply *dynamic imagery* in their imagery practice (Holmes and Collins 2001). Researchers had noted that athletes engaged in either *synchronous movements* (e.g., moving the appropriate limbs to simulate the executed skill) or *asynchronous movements* (e.g., other movements in which, for example, their hand may simulate the carving movement of a surfboard) during imagery (MacIntyre and Moran 2010). Interestingly, a broad definition of mental imagery encompasses coactivation of simulation and motor execution processes to account for dynamic imagery (Morris, Spittle, and Watt 2005).

A number of studies within sport psychology suggest that motor imagery is superior to visual imagery in improving athlete's performance (Driskell, Copper, and Moran 1994). Guillot, Moschberger, and Collet (2013) conducted a study with twelve elite high-jump athletes to test the hypothesis that movement during imagery would enhance the participants' imagery. Their measure was temporal accuracy—the comparison between duration of simulation and motor execution of the run-up jump and landing for dynamic imagery and motionless imagery. They reported a significant difference between imagery and actual times when participants performed motionless imagery. In contrast, they achieved temporal congruence during dynamic imagery. Furthermore, ratings on the quality of their imagery supported previous quasi-experimental findings (Callow, Roberts, and Fawkes 2006) and qualitative reports. For instance, in another study. one elite-level canoe-slalom competitor explained, "It can help … if you move your arms in a similar motion as you're going to move them in the boat, it can help with the timing a little bit more and you can sort of feel how you're anticipating" (MacIntyre and Moran 2007). While one can tentatively conclude that the evidence suggests athletes find this beneficial, it requires further study.

The implications of these findings go beyond the performance-enhancement role, however, and question the traditional definitions of motor imagery as occurring without *any* overt motor output. Jeannerod's (1994, 2006) action-simulation model proposes that imagery processes are involved in motor planning (covert process), and this enables the off-line simulation of action. As noted earlier, motor imagery is part of the action spectrum, with other simulation activities on this spectrum including *shadow shots* (e.g., a low-amplitude post-execution practice swing) and *action-observation*, which have varying degrees of motor activation, potential for motor output, and visual cognition. As we shall see later in this chapter, sport experts have demonstrated specific metacognitive expertise that enables them to control and manage their action-simulation processes. These expertise effects have consequences for our future research directions. First, we should consider the breadth of evidence supporting the grounded cognition approach within motor imagery research.

Recently, Ionta et al. (2012) reported that variations in the hand position of participants during mental rotations tasks influenced the latencies for congruent stimuli. They concluded that sensorimotor and postural information coming from the body might influence mental rotation of body parts according to specific, somatotopic rules. These preliminary findings were congruent with the *body-specificity hypothesis*, which claims that body-specific patterns of motor experience shape the way we think (Casasanto 2011, 2014). An interesting study tested this same concept of the *body-specificity hypothesis* using the mental travel paradigm. Body position was controlled across different conditions to be either congruent or incongruent with the action (e.g., standing: congruent with walking; sitting: incongruent with walking), and the duration of the motor imagery was compared across the conditions (Saimpont et al. 2012). Using both elderly and youth samples, the researchers reported that simulation times in the congruent (standing) position were closer to actual walking times, and this effect appeared to be maintained across the lifespan. Furthermore, research by Ionta and colleagues (2013) has provided evidence that motor constraints—for example, anatomically plausible versus illusory posture—affects the mental rotation of body parts. Imagery of heavy objects has been demonstrated to increase the duration of response times relative to motor imagery of lighter objects (Ionta et al. 2012). Furthermore, future findings from this line of inquiry may have ramifications for the recent accounts of embodiment and cognition (Borghi and Cimatti 2010; Gallese and Sinigaglia 2011).

Providing further evidence that cognition is embodied, rather than merely being fully explained by an information-processing approach, is a range of findings that demonstrate an interaction between motor and cognitive processes. For example, Gentilucci and Gangitano (1998) demonstrated this directly, wherein people differentially reached toward blocks that had the words "long" and "short" printed on them. Specifically, peak reaching acceleration, velocity, and deceleration were higher for the "long" block, even though the two blocks were identical in physical dimensions. Similarly, Gentilucci et al. (2000) observed differences in reaching toward blocks that had the words "near" and "far" printed on them, but not in a control condition in which the words on the block were unrelated to motor actions. Glover et al. (2004) demonstrated that these effects of language on motor actions are not constrained to words directly related to motor actions, but that words representing the names of relatively large and small graspable objects (e.g., "apple" and "grape," respectively) can influence peak grip aperture. These differences provide evidence that cognitive processes can influence overt motor execution. Functional properties of objects represented by words and images have been shown to influence later memory (Madan and Singhal 2012c) and have been associated with automatic motor simulations (Madan, Chen, and Singhal 2016).

4 What Can We Learn from Experts?

Individual differences in imagery abilities have been acknowledged by researchers since the time of Galton (1880). Evidence for consistent differences in imagery abilities related to sporting expertise has emerged (Milton et al. 2007). For example, studies with elite performers have indicated that they have more advanced imagery abilities than their non-elite counterparts (MacIntyre et al. 2013; MacIntyre and Moran 2010). This also includes metacognitive knowledge (Dunlosky and Metcalfe 2009) or, more specifically, meta-imagery, which is athletes' knowledge of, and control over, their own mental imagery skills and experiences (Moran 2002). Imagery ability is a moderating variable in the mental practice effect (Driskell, Copper, and Moran 1994). In other words, those with greater proficiency on imagery ability tests gain more from mental practice than their less-proficient counterparts. This may be due to more experienced performers having a more accurate representation of their movement. For example, a novice may not have knowledge about the grip, stance, and target area during mental practice of a free throw and thus may gain little from the rehearsal. Mental travel research, in which the duration of simulated and executed motor skills are compared, also supports expertise effects (Guillot and Collet 2008). Not surprisingly, numerous studies have shown motor imagery ability to be a promising indicator of an athlete's success (Madan and Singhal 2012a).

The aforementioned expertise effects provided an impetus for motor cognition researchers to explore the natural laboratory of sport. This emphasis on investigating the abilities of experts has been termed the *strength-based approach* (MacIntyre et al. 2013). It augments the prototypical *deficit-based approach*, which comprised both patients and healthy subjects and may have overlooked the potential for unique insights from those who are highly skilled on imagery ability measures. Rather than replacing traditional paradigms, this approach simply widens the net based on specific criterion for expertise (MacIntyre et al. 2013). The strength-based approach isn't simply preselecting athlete samples or those who excel on a task. It includes those who demonstrate specialist learning and abilities.

One such example is the patient IW, who suffered from chronic deafferentation and had been a participant in over two decades of research. A recent case study with the patient IW used mental rotation of animate versus inanimate stimuli to investigate if his imagery abilities reflected his impaired motor system (Horst et al. 2012). The authors reported that IW's motor imagery processes were impaired but that visual imagery processes were enhanced compared with controls. This relative expertise is important to recognize, as in this case it helped the patient overcome the fundamental challenge to his motor system by developing his visual imagery ability.

Similarly, much is still to be learned from the comparison of patient and non-patient groups, as recent mental travel research has demonstrated (Fusco et al. 2014, 2016). The implications of research using the strength-based approach are even greater for those engaged in performance domains, for example, participants in elite sport (Beilock 2008; MacIntyre et al. 2013) and professional dance (Bläsing, Puttke, and Schack 2010; Calvo-Merino et al. 2005, 2006: Nordin and Cumming 2005). A potential bidirectional benefit may occur from research insights with these participants, as not only may theories be tested but, moreover, knowledge that may benefit performance also may arise from such research (Cappuccio 2015).

5 Five Questions to Be Answered

5.1 To What Extent Is Our Knowledge Constrained by Neural Operations That Embody Previous Actions and Experiences?

Those with extensive motor skill experience in a particular domain should represent information in that domain quite differently than those without such experiences, even when there is no intention to act. Is motor imagery grounded in our prior experiences? Tentative evidence suggests that this is the case with regard to expert-novice differences (Jansen and Lehmann 2013; Olsson and Nyberg 2012). Expertise effects among mental imagery abilities have been demonstrated among dancers (Bläsing, Puttke, and Schack 2010). Furthermore, Olsson and Nyberg (2012), in their comparative study of a wheelchair athlete and a control sample, used fMRI of motor imagery of stair walking and wheelchair slalom to show that only tasks that we have physical experience of recruit the motor system. More recently, Jansen and Lehmann (2013), in a mental rotation study, reported higher mental rotation accuracy for human figures compared to cubed figures for athletic samples compared to non-athletes. They concluded that their study added to the literature of the coupling of perception and action and deserves further attention in the literature on embodied cognition. They recommended taking consideration of prior expertise in body representation in future investigations of the extent to which cognitive processes are rooted in the body and its interaction with the world.

One question for researchers is whether we need to measure movement abilities to study motor imagery. It may be necessary not only to account for current body posture during a motor imagery protocol but also to evaluate participant abilities for specific movements. For example, if exploring golfers' expertise, it may be useful to measure their putting ability and consistency prior to a study on simulated putting (MacIntyre et al. 2013). This may be of particular interest in illuminating our understanding of the developmental trajectory of cognitive abilities, including motor imagery, that may be influenced by developmental milestones in motor capacity (Gabbard 2013).

5.2 Can Measures of Imagery Ability Be Used to Advance Our Understanding of Embodied Cognition?

As a complementary approach to manipulating motor imagery within a cognitive task, inter-individual ability can be evaluated using questionnaires. The most common questionnaires of motor imagery ability were inspired by the Vividness of Visual Imagery Questionnaire (VVIQ) (Marks 1973), which asked participants to imagine a visual scene and then to judge the vividness of the imagery on a Likert scale. The related motor imagery questionnaires are the Vividness of Movement Imagery Questionnaire (VMIQ) (Isaac, Marks, and Russell 1986; also see Roberts et al. 2008) and the Movement Imagery Questionnaire (MIQ) (Hall and Pongrac 1983; Hall, Pongrac, and Buckholz 1985; also see Gregg, Hall, and Butler 2010). Eton, Gilner, and Munz (1998) found that the VMIQ, but not the VVIQ, differed between athletes and nonathletes. Furthermore, VMIQ scores were significantly correlated with self-assessments of imagery use (e.g., "Do you use mental imagery to enhance sport performance?"). Unfortunately, because these questionnaires are subjective, non-imagery factors may also influence responses. For instance, participants may calibrate their vividness responses to be consistent with their own views of their deliberate use of motor imagery and motor skills.

As an alternative approach, objective measures of motor imagery—in which there is a correct response, rather than a subjective Likert scale—may provide a less biased assessment of the role of motor imagery in sports. One such measure is the Test of Ability in Movement Imagery (TAMI) (Madan and Singhal 2013, 2014). In the TAMI, participants are instructed to imagine a series of five movement instructions that manipulate the head, arm/hand, torso, or leg/foot. After reading the instructions, participants flip to the response page and must select from a set of five body-positioning images, along with the options "none of the above" and "unclear." The TAMI consists of ten questions, preceded by a practice question.

The TAMI was further refined to a weighted-scoring procedure, wherein more difficult questions are weighted more heavily, specifically to improve sensitivity for use with athlete populations (Madan and Singhal 2014). The general procedure of the TAMI was inspired by the Controllability of Motor Imagery Test (CMI) (Nishida et al. 1986). There are a variety of motor imagery tests, and consideration is needed when determining which may be the most appropriate measure for a given research question. For instance, while it is well known that there are sex differences in the mental rotations test (Parsons 1987; Peters et al. 1995; Voyer 2011), sex differences were not found in the TAMI (Madan and Singhal 2015). The literature contains many useful measures of inter-individual ability in motor imagery, including some designed specifically within the domain of sport psychology. Careful consideration is necessary when selecting the appropriate measures (both subjective and objective) for evaluating imagery ability, and future research is necessary to understand how these imagery questionnaires relate to extant approaches for studying embodied cognition.

5.3 Can Motor Imagery and Embodied Cognition Provide a Portal into Our Emotional State?

Previously researchers have utilized embodied cognition perspectives to elucidate our understanding of choking behavior in sport (Beilock 2008; Cappuccio 2015; see also Montero, Toner, and Moran, this volume). Interestingly, recent research has demonstrated that motor retardation, a symptom of depression, is also evident during motor imagery tasks (Chen et al. 2013). To explain, a slowdown in motor execution has been reported in mental rotation studies that compared differences between the response times for two sets of stimuli. Briefly, in a study with patients with unipolar depression, their mental rotation of animate stimuli reflected slower reaction times in comparison with the latencies for another condition that used inanimate stimuli (e.g., block objects). This raises an interesting question for researchers: Does this impairment reflect our negative emotional state through embodied cognition? Evidence for these effects are accumulating (Bennabi et al. 2014), but research is required with those with less-profound emotional distress to explore whether our action system and simulation processes convey mood disturbances across the spectrum (i.e., positive and negative mood). For example, injured athletes compared with those in flow state may differ vastly both in their emotional state and their ability to react to stimuli; the possibility of developing implicit measures of mood state from motor imagery research remains.

5.4 Can Embodied Cognition Perspectives Help Optimize Injury Recovery and Rehabilitation?

Mental imagery more broadly and, indeed, motor imagery have been widely recommended as interventions for injury recovery for athletes (Callow and Roberts 2010; Driediger, Hall, and Callow 2006). The psychological consequences of sport injury are often profound, with psychological distress commonly reported (Brewer 2010). For example, in a qualitative study with injured athletes, Driediger, Hall, and Callow (2006) reported that athletes experienced negative or debilitative images (e.g., imagining failing to return to play). This type of imagery may increase athletes' fear of reinjury and provide a significant obstacle in their return to play by reducing their adherence to rehabilitation protocols. Thus it is paramount that, if an imagery intervention is employed, specific recommendations are followed to enhance the psychological recovery (i.e., reduce fear of reinjury). Limited evidence supports mental imagery being applied as a global recovery strategy, as individual differences in imagery ability, among other factors, should be considered. Imagery rescripting (reediting the imagery to ensure it's facilitative) offers a promising therapeutic strategy that has been previously demonstrated among clinical patients (Holmes et al. 2015). It is necessary to develop specific protocols for performance enhancement to ensure the goals set are achieved. For example, McIsaac and Eich (2004) reported that traumatic images retrieved from a third-person perspective were experienced as less emotional than those retrieved from a first-person perspective. An interesting topic for study would be the evaluation of the relative efficacy of different perspectives (which may involve different levels of embodiment) in rescripting imagery interventions. Moreover, the role of prospective positive images (e.g., return to play) may be more valuable than simply using imagery of skill acquisition (Brewer 1994). For example, Baird, Smallwood, and Schooler (2011) found that positive constructive daydreaming tends to be future-oriented and that those with greater working memory assets are more likely to engage in future-oriented daydreaming. Thus, idle working memory resources are essential to adaptive, prospective daydreaming. Whereas retrospective mind wandering tends to be loosely related to personal goals, Baird, Smallwood, and Schooler (2011) conclude that spontaneous prospective thought is adaptive because it advances personally relevant goals, and embodied cognition may be central to elucidating our understanding of such daydreaming or spontaneous mental imagery (McMillan, Kaufman, and Singer 2013).

The implications for recovery from sport injury may also have consequences for those with impairments to their neural function (e.g., stroke patients). Motor imagery has been employed in stroke rehabilitation with varying degrees of success (Grangeon et al. 2012). A greater understanding of the role of embodiment in cognition undoubtedly has implications for the application of mental imagery as an injury-recovery strategy and rehabilitation strategy.

5.5 Does Our Perception of Our Environment Have Implications for Our Cognition and Emotional State?

Adams and Galinsky (2012) proposed the concept of *enclothed cognition* to illustrate the interaction between what we wear and our cognition. They posited that the term *enclothed cognition* encompassed "the effects of clothing on people's psychological processes" which "depend on both a) the symbolic meaning of the clothes and b) whether people are actually wearing the clothes" (919). The broader environment may indeed have a wider influence on our cognition than has been previously thought. For example, exercise and physical activity in natural spaces—what has been termed *green exercise*—has distinct effects on our attentional capacity and emotions (Barton and Pretty 2010). Emerging evidence suggests that even rambling on a forest trail can enhance working memory capacity (a process called *attention restoration*; e.g., Kaplan 1995) relative to the similar physical activity in an urban setting. The differences between urban and rural settings are potentially substantial in terms of visual stimuli, social factors (i.e., whether solitary or social activity), and environmental factors like air pollution and noise, but other factors may also be at play here. Walking is a complex motor behavior with a special relevance in social interactions (for review, see Pavlova 2012). By observing walking, people can extract a considerable amount of information, including emotional states and intentions of the agent (Dalla Volta et al. 2015). Natural environments provide a rich sensory experience, often without the threat (e.g., crime) or risk (e.g., traffic) obvious in other settings. Walking supports various psychological mechanisms for reconciliation, including creativity, locomotion motivation, and embodied notions of forward progress (Webb, Rossignac-Milon, and Higgins 2017). Another possibility is that the vividness of our memories of these natural experiences (e.g., walk along a beach), mediated by embodied cognition, provides a multisensory episodic procedural memory that gives green exercise its *sticky behavior effect* (i.e., increased adherence and higher propensity for future engagement). Embodied cognition should be considered a worthy framework from which to investigate green exercise and other nature-based solutions for well-being.

6 Conclusion

One commonality between embodied cognition and motor imagery is their long past in philosophical discourse but relatively short empirical history within psychology. Nevertheless, criticism still abounds, and scientific debate is seldom far from both imagery (Madan and Singal 2012a; Pylyshyn 2002) and embodied cognition (Gallese and Sinigaglia 2011; Glenberg 2015; Mahon and Caramazza 2008). Nevertheless, a notable benefit of the shared interest in these topics from psychologists (including practitioners), neuroscientists, and philosophers is the potential synergies that arise from the interdisciplinary discourse. This arguably will develop new avenues of research with the potential to create more comprehensive understanding of the human mind (Denis 2012). It is possible that transdisciplinary approaches will emerge from the fusion of research questions from both paradigms. As Stock and Stock (2004) noted in their historical review of ideomotor theory, we should not forget to learn from its past. It is apparent that William James's research, which expounded on the confluence of action and motor imagery, has finally come of age.

References

Adam, H., and A. D. Galinsky. 2012. "Enclothed Cognition." *Journal of Experimental Social Psychology* 48 (4): 918–925. http://dx.doi.org/10.1016/j.jesp.2012.02.008.

Adams, Jack A. 1987. "Historical Review and Appraisal of Research on the Learning, Retention, and Transfer of Human Motor Skills." *Psychological Bulletin* 101 (1): 41–74. doi:10.1037//0033-2909.101.1.41.

Arora, Sonal, Rajesh Aggarwal, Pramudith Sirimanna, Aidan Moran, Teodor Grantcharov, Roger Kneebone, Nick Sevdalis, and Ara Darzi. 2011. "Mental Practice Enhances Surgical Technical Skills: A Randomized Controlled Study." *Obstetrical and Gynecological Survey* 66 (6): 336–338. doi:10.1097/ogx.0b013e31822c17e1.

Baird, B., J. Smallwood, and J. W. Schooler. 2011. "Back to the Future: Autobiographical Planning and the Functionality of Mind-Wandering." *Conscious and Cognition* 20:1604–1611. doi: 10.1016/j.concog.2011.08.007

Barsalou, Lawrence W. 2008. "Grounded Cognition." *Annual Review of Psychology* 59:617–645.

Bartlett, Frederic. 1932. *Remembering: A Study in Experimental and Social Psychology*. Cambridge: Cambridge University Press.

Barton, Jo, and Jules Pretty. 2010. "What Is the Best Dose of Nature and Green Exercise for Improving Mental Health? A Multi-Study Analysis." *Environmental Science and Technology* 44 (10): 3947–3955.

Beilock, Sian L. 2008. "Beyond the Playing Field: Sport Psychology Meets Embodied Cognition." *International Review of Sport and Exercise Psychology* 1 (1): 19–30. doi:10.1080/17509840701836875.

Belardinelli, Marta Olivetti, Rosalia Di Matteo, Cosimo Del Gratta, Andrea De Nicola, Antonio Ferretti, Armando Tartaro, Lorenzo Bonomo, and Gian Luca Romani. 2004. "Intermodal Sensory Image Generation: An fMRI Analysis." *European Journal of Cognitive Psychology* 16 (5): 729–752. doi:10.1080/09541440340000493.

Belardinelli, M. Olivetti, M. Palmiero, C. Sestieri, D. Nardo, R. Di Matteo, A. Londei, A. D'Ausilio, A. Ferretti, C. Del Gratta, and G. L. Romani. 2009. "An fMRI Investigation on Image Generation in Different Sensory Modalities: The Influence of Vividness." *Acta Psychologica* 132 (2): 190–200. doi:10.1016/j.actpsy.2009.06.009.

Bennabi, Djamila, Julie Monnin, Emmanuel Haffen, Nicolas Carvalho, Pierre Vandel, Thierry Pozzo, and Charalambos Papaxanthis. 2014. "Motor Imagery in Unipolar Major Depression." *Frontiers in Behavioral Neuroscience* 8 (December): 413. doi:10.3389/fnbeh.2014.00413.

Bergen, Benjamin K. 2012. *Louder than Words: The New Science of How the Mind Makes Meaning*. New York: Basic Books.

Betts, George Herbert. 1909. *The Distribution and Functions of Mental Imagery*. New York: Teachers College, Columbia University.

Bläsing, Bettina, Martin Puttke, and Thomas Schack. 2010. *The Neurocognition of Dance: Mind, Movement and Motor Skills*. London: Psychology Press.

Borghi, Anna M., and Felice Cimatti. 2010. "Embodied Cognition and Beyond: Acting and Sensing the Body." *Neuropsychologia* 48 (3): 763–773. doi:10.1016/j.neuropsychologia.2009.10.02.

Borghi, Anna M., and Diane Pecher. 2011. "Introduction to the Special Topic: Embodied and Grounded Cognition." *Frontiers in Psychology* 2 (August): 187. doi:10.3389/fpsyg.2011.00187.

Borghi, Anna M., Claudia Scorolli, Daniele Caligiore, Gianluca Baldassarre, and Luca Tummolini. 2013. "The Embodied Mind Extended: Using Words as Social Tools." *Frontiers in Psychology* 4 (May): 214. doi:10.3389/fpsyg.2013.00214.

Brewer, Britton W. 1994. "Review and Critique of Models of Psychological Adjustment to Athletic Injury." *Journal of Applied Sport Psychology* 6:87–100.

Brewer, Britton W. 2010. "The Role of Psychological Factors in Sport Injury Rehabilitation Outcomes." *International Review of Sport and Exercise Psychology* 3 (1): 40–61. doi:10.1080/17509840903301207.

Bufalari, I., A. Sforza, P. Cesari, S. M. Aglioti, and A. D. Fourkas. 2010. "Motor Imagery beyond the Joint Limits: A Transcranial Magnetic Stimulation Study." *Biological Psychology* 85 (2): 283–290. doi:10.1016/j.biopsycho.2010.07.015.

Callow, Nichola, and Ross Roberts. 2010. "Imagery Research: An Investigation of Three Issues." *Psychology of Sport and Exercise* 11 (4): 325–329. doi:10.1016/j.psychsport.2010.03.002.

Callow, Nichola, Ross Roberts, and Joanna Z. Fawkes. 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). doi:10.2202/1932-0191.1001.

Calvo, Paco, and Toni Gomila. 2008. *Handbook of Cognitive Science: An Embodied Approach*. Amsterdam: Elsevier Science.

Calvo-Merino, B., D. E. Glaser, J. Grèzes, R. E. Passingham, and P. Haggard. 2005. "Action Observation and Acquired Motor Skills: An FMRI Study with Expert Dancers." *Cerebral Cortex* 15 (8): 1243–1249. doi:10.1093/cercor/bhi007.

Calvo-Merino, Beatriz, Julie Grèzes, Daniel E. Glaser, Richard E. Passingham, and Patrick Haggard. 2006. "Seeing or Doing? Influence of Visual and Motor Familiarity in Action Observation." *Current Biology* 16 (22): 2277. doi:10.1016/j.cub.2006.10.065.

Cappuccio, Massimiliano L. 2015. "Introduction: When Embodied Cognition and Sport Psychology Team-Up." *Phenomenology and the Cognitive Sciences* 14 (2): 213–225. doi:10.1007/s11097-015-9415-1.

Casasanto, Daniel. 2011. "Different Bodies, Different Minds." *Current Directions in Psychological Science* 20 (6): 378–383. doi:10.1177/0963721411422058.

Casasanto, Daniel. 2014. "Bodily Relativity." In *Routledge Handbook of Embodied Cognition*, edited by L. Shapiro, 108–117. London: Routledge.

Chen, J., L. Q. Yang, Z. J. Zhang, W. T. Ma, X. Q. Wu, Zhang X. R., D. H. Wei, et al. 2013. "The Association between the Disruption of Motor Imagery and the Number of Depressive Episodes of Major Depression." *Journal of Affective Disorder* 150 (2): 337–343. doi:10.1016/j.jad.2013.04.015.

Cornoldi, C., and R. De Beni. 2012. "Foreword." In *Essays in Honour of Michel Denis: From Mental Imagery to Spatial Cognition and Language*, edited by V. Gyselinck and F. Pazzaglia, ix–x. Sussex: Psychology Press.

Dalla Volta, Riccardo, Fabrizio Fasano, Antonio Cerasa, Graziella Mangone, Aldo Quattrone, and Giovanni Buccino. 2015. "Walking Indoors, Walking Outdoors: An fMRI Study." *Frontiers in Psychology* 6 (October): 1502. doi:10.3389/fpsyg.2015.01502.

De Lange, Floris P., Karin Roelofs, and Ivan Toni. 2008. "Motor Imagery: A Window into the Mechanisms and Alterations of the Motor System." *Cortex* 44 (5): 494–506. doi:10.1016/j.cortex.2007.09.002.

Denis, Michel. 2012. "Decades of Images: Reminiscences of a Shared Scientific Journey." In *Essays in Honour of Michel Denis: From Mental Imagery to Spatial Cognition and Language,* edited by V. Gyselinck and F. Pazzaglia, 203–244. Sussex: Psychology Press.

Driediger, Molly, Craig Hall, and Nichola Callow. 2006. "Imagery Use by Injured Athletes: A Qualitative Analysis." *Journal of Sports Sciences* 24 (3): 261–272. doi:10.1080/02640410500128221.

Driskell, James E., Carolyn Copper, and Aidan Moran. 1994. "Does Mental Practice Enhance Performance?" *Journal of Applied Psychology* 79 (4): 481–492. doi:10.1037//0021-9010.79.4.481.

Dunlosky, J., and J. Metcalfe, eds. 2009. *Metacognition: A Textbook of Cognition, Educational, Life Span, and Applied Psychology*. Thousand Oaks, CA: Sage.

Eton, D. T., F. H. Gilner, and D. C. Munz. 1998. "The Measurement of Imagery Vividness: A Test of the Reliability and Validity of the Vividness of Visual Imagery Questionnaire and the Vividness of Movement Imagery Questionnaire." *Journal of Mental Imagery* 22:125–136.

Fourkas, Alissa D., Silvio Ionta, and Salvatore M. Aglioti. 2006. "Influence of Imagined Posture and Imagery Modality on Corticospinal Excitability." *Behavioural Brain Research* 168 (2): 190–196. doi:10.1016/j.bbr.2005.10.015.

Fusco, Augusto, Maria Chiara Gallotta, Marco Iosa, Giovanni Morone, Luigi Iasevoli, Domenica Trifoglio, Vincenzo Maria Saraceni, Stefano Paolucci, Carlo Baldari, and Laura Guidetti. 2016. "The Dynamic Motor Imagery of Locomotion Is Task-Dependent in Patients with Stroke." *Restorative Neurology and Neuroscience* 34 (2): 247–256. doi:10.3233/rnn-150573.

Fusco, Augusto, Marco Iosa, Maria Chiara Gallotta, Stefano Paolucci, Carlo Baldari, and Laura Guidetti. 2014. "Different Performances in Static and Dynamic Imagery and Real Locomotion:

An Exploratory Trial." *Frontiers in Human Neuroscience* 8 (October): 760. doi:10.3389/fnhum.2014.00760.

Gabbard, Carl. 2013. "The Role of Mental Simulation in Embodied Cognition." *Early Child Development and Care* 183 (5): 643–650. http://dx.doi.org/10.1080/03004430.2012.681649.

Gallese, Vittorio, and Corrado Sinigaglia. 2011. "What Is So Special about Embodied Simulation?" *Trends in Cognitive Sciences* 15 (11): 512–519. doi:10.1016/j.tics.2011.09.003.

Galton, Francis. 1880. "Statistics of Mental Imagery." *Mind* 19:301–318.

Ganis, G., J. P. Keenan, S. M. Kosslyn, and A. Pascual-Leone. 2000. "Transcranial Magnetic Stimulation of Primary Motor Cortex Affects Mental Rotation." *Cerebral Cortex* 10 (2): 175–180. doi:10.1093/cercor/10.2.175.

Gentilucci, M., F. Benuzzi, L. Bertolani, E. Daprati, and M. Gangitano. 2000. "Language and Motor Control." *Experimental Brain Research* 133 (4): 468–490. doi:10.1007/s002210000431.

Gentilucci, Maurizio, and Massimo Gangitano. 1998. "Influence of Automatic Word Reading on Motor Control." *European Journal of Neuroscience* 10 (2): 752–756. doi:10.1046/j.1460-9568.1998.00060.x.

Gibson, James J. 1979. *The Ecological Approach to Visual Perception*. Boston: Houghton Mifflin.

Glenberg, Arthur M. 2015. "Few Believe the World Is Flat: How Embodiment Is Changing the Scientific Understanding of Cognition." *Canadian Journal of Experimental Psychology / Revue Canadienne de Psychologie Experimentale* 69 (2): 165–171. doi:10.1037/cep0000056.

Glover, Scott. 2004. "Separate Visual Representations in the Planning and Control of Action." *Behavioral and Brain Sciences* 27 (1): 3–24; discussion 24–78.

Glover, Scott, and Marek Baran. 2017. "The Motor-Cognitive Model of Motor Imagery: Evidence from Timing Errors in Simulated Reaching and Grasping." *Journal of Experimental Psychology: Human Perception and Performance* 43 (7): 1359–1375. doi:10.1037/xhp0000389.

Goldinger, Stephen D., Megan H. Papesh, Anthony S. Barnhart, Whitney A. Hansen, and Michael C. Hout. 2016. "The Poverty of Embodied Cognition." *Psychonomic Bulletin and Review* 23 (4): 959–978.

Grangeon, M., P. Revol, A. Guillot, G. Rode, and C. Collet. 2012. "Could Motor Imagery Be Effective in Upper Limb Rehabilitation of Individuals with Spinal Cord Injury? A Case Study." *Spinal Cord* 50 (10): 766–771. doi:10.1038/sc.2012.41.

Gregg, M., C. Hall, and A. Butler. 2010. "The MIQ-RS: A Suitable Option for Examining Movement Imagery Ability." *Evidence-Based Complementary and Alternative Medicine(eCAM)* 7 (2): 249–257. http://doi.org/10.1093/ecam/nem170.

Guillot, Aymeric, and Christian Collet. 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 (1): 31–44. doi:10.1080/17509840701823139.

Guillot, Aymeric, and Christian Collet. 2010. *The Neurophysiological Foundations of Mental and Motor Imagery*. Oxford: Oxford University Press.

Guillot, Aymeric, Franck Di Rienzo, Tadhg Macintyre, Aidan Moran, and Christian Collet. 2012. "Imagining Is Not Doing but Involves Specific Motor Commands: A Review of Experimental Data Related to Motor Inhibition." *Frontiers in Human Neuroscience* 6. doi:10.3389/fnhum.2012.00247.

Guillot, Aymeric, Kevin Moschberger, and Christian Collet. 2013. "Coupling Movement with Imagery as a New Perspective for Motor Imagery Practice." *Behavioral and Brain Functions* 9 (February): 8. doi:10.1186/1744-9081-9-8.

Hall, Craig R., and J. Pongrac. 1983. Movement Imagery Questionnaire. In Craig Hall, John Pongrac, and Eric Buckholz, "The Measurement of Imagery Ability." *Human Movement Science* 4 (June 1985): 107–118. doi: 10.1016/0167-9457(85)90006-5.

Hall, C. R., J. Pongrac, and E. Buckolz. 1985. "The Measurement of Imagery Ability." *Human Movement Science* 4: 107–118.

Hardy, Lew, J. Graham Jones, and Daniel Gould. 1996. *Understanding Psychological Preparation for Sport: Theory and Practice of Elite Performers*. Chichester, UK: J. Wiley.

Holmes, Emily A., Lalitha Iyadurai, Gitta A. Jacob, and Susie Hales. 2015. "Mental Imagery in Psychological Disorders." In *Emerging Trends in the Social and Behavioral Sciences: An Interdisciplinary, Searchable, and Linkable Resource*, edited by Stephen M. Kosslyn, Robert A. Scott, and Marlis C. Buchmann, 1–15. Hoboken, NJ: John Wiley and Sons. doi:10.1002/9781118900772.etrds0216.

Holmes, Paul S., and David J. Collins. 2001. "The PETTLEP Approach to Motor Imagery: A Functional Equivalence Model for Sport Psychologists." *Journal of Applied Sport Psychology* 13:60–83.

Horst, Arjan C. Ter, Jonathan Cole, Rob van Lier, and Bert Steenbergen. 2012. "The Effect of Chronic Deafferentation on Mental Imagery: A Case Study." *PLoS ONE* 7 (8): e42742. doi:10.1371/journal.pone.0042742.

Ionta, Silvio, David Perruchoud, Bogdan Draganski, and Olaf Blanke. 2012. "Body Context and Posture Affect Mental Imagery of Hands." *PLoS ONE* 7 (3): e34382. doi:10.1371/journal.pone.0034382.

Ionta, Silvio, Anna Sforza, Mariko Funato, and Olaf Blanke. 2013. "Anatomically Plausible Illusory Posture Affects Mental Rotation of Body Parts." *Cognitive, Affective and Behavioral Neuroscience* 13 (1): 197–209. doi:10.3758/s13415-012-0120-z.

Isaac, Anne, David F. Marks, and David G. Russell. 1986. "An Instrument for Assessing Imagery of Movement: The Vividness of Movement Imagery Questionnaire (VMIQ)." *Journal of Mental Imagery* 10 (4): 23–30.

Jackson, Philip L., and Jean Decety. 2004. "Motor Cognition: A New Paradigm to Study Self-Other Interactions." *Current Opinion in Neurobiology* 14 (2): 259–263. doi:10.1016/j.conb.2004.01.020.

James, William. 1890. *The Principles of Psychology*. New York: Henry Holt.

Jansen, Petra, and Jennifer Lehmann. 2013. “Mental Rotation Performance in Soccer Players and Gymnasts in an Object-Based Mental Rotation Task.” *Advances in Cognitive Psychology* 9 (2): 92–98. http://doi.org/10.2478/v10053-008-0135-8.

Jansen, Petra, Jennifer Lehmann, and Jessica Van Doren. 2012. “Mental Rotation Performance in Male Soccer Players.” *PLoS ONE* 7 (10): e48620. https://doi.org/10.1371/journal.pone.0048620.

Jeannerod, Marc. 1994. “The Representing Brain: Neural Correlates of Motor Intention and Imagery.” *Behavioral and Brain Sciences* 17 (2): 187–202. doi:10.1017/s0140525x00034026.

Jeannerod, Marc. 2006. *Motor Cognition: What Actions Tell the Self*. Oxford: Oxford University Press.

Kaplan, Stephen. 1995. “The Restorative Benefits of Nature: Toward an Integrative Framework.” *Journal of Environmental Psychology* 15 (3): 169–182. doi:10.1016/0272-4944(95)90001-2.

Kosslyn, Stephen M., Gregory J. Digirolamo, William L. Thompson, and Nathaniel M. Alpert. 1998. “Mental Rotation of Objects versus Hands: Neural Mechanisms Revealed by Positron Emission Tomography.” *Psychophysiology* 35 (2): 151–161. doi:10.1111/1469-8986.3520151.

Kosslyn, Stephen M., Carol Seger, John R. Pani, and Lynn A. Hillger. 1990. “When Is Imagery Used in Everyday Life? A Diary Study.” *Journal of Mental Imagery* 14:131–152.

Kosslyn, Stephen M., and A. L. Sussman. 1995. “Roles of Imagery in Perception: Or, There Is No Such Thing as Immaculate Perception.” In *Cognitive Neurosciences,* edited by Michael S. Gazzaniga, 1035–1042. Cambridge, MA: MIT Press.

Kosslyn, Stephen M., William L. Thompson, and Giorgio Ganis. 2006. *The Case for Mental Imagery*. Oxford: Oxford University Press.

Kosslyn, Stephen M., William L. Thompson, M. Wraga, and Nathaniel M. Alpert. 2001. “Imagining Rotation by Endogenous versus Exogenous Forces: Distinct Neural Mechanisms.” *NeuroReport* 12 (11): 2519–2525. doi:10.1097/00001756-200108080-00046.

Loeffler, Jonna, Markus Raab, and Rouwen Cañal-Bruland. 2016. “A Lifespan Perspective on Embodied Cognition.” *Frontiers in Psychology* 7 (June): 845. doi:10.3389/fpsyg.2016.00845.

Lorey, Britta, Matthias Bischoff, Sebastian Pilgramm, Rudolf Stark, Jörn Munzert, and Karen Zentgraf. 2009. “The Embodied Nature of Motor Imagery: The Influence of Posture and Perspective.” *Experimental Brain Research* 194 (2): 233–243. doi:10.1007/s00221-008-1693-1.

Lynott, Dermot, Louise Connell, and Judith Holler. 2013. “The Role of Body and Environment in Cognition.” *Frontiers in Psychology* 4 (July): 465. doi:10.3389/fpsyg.2013.00465.

MacIntyre, Tadhg E., Eric R. Igou, Mark J. Campbell, Aidan P. Moran, and James Matthews. 2014. “Metacognition and Action: A New Pathway to Understanding Social and Cognitive Aspects of Expertise in Sport.” *Frontiers in Psychology* 5 (October): 1155. doi:10.3389/fpsyg.2014.01155.

MacIntyre, Tadhg, and Aidan Moran. 2007. “A Qualitative Investigation of Imagery Use and Meta-Imagery Processes among Elite Canoe-Slalom Competitors.” *Journal of Imagery Research in Sport and Physical Activity*, 2 (1). doi: 10.2202/1932-0191.1009.

MacIntyre, Tadhg, and Aidan Moran. 2010. "Meta-Imagery Processes among Elite Sports Performers." In *The Neurophysiological Foundations of Mental and Motor Imagery*, edited by A. Guillot and C. Collet, 227–244. New York: Oxford University Press.

MacIntyre, Tadhg E., Aidan P. Moran, Christian Collet, and Aymeric Guillot. 2013. "An Emerging Paradigm: A Strength-Based Approach to Exploring Mental Imagery." *Frontiers in Human Neuroscience* 7 (April): 104. doi:10.3389/fnhum.2013.00104.

Madan, Christopher R., and Anthony Singhal. 2012a. "Motor Imagery and Higher-Level Cognition: Four Hurdles before Research Can Sprint Forward." *Cognitive Processing* 13 (3): 211–229. doi:10.1007/s10339-012-0438-z.

Madan, Christopher R., and Anthony Singhal. 2012b. "Using Actions to Enhance Memory: Effects of Enactment, Gestures, and Exercise on Human Memory." *Frontiers in Psychology* 3 (November): 507. doi:10.3389/fpsyg.2012.00507.

Madan, Christopher R., and Anthony Singhal. 2012c. "Encoding the World around Us: Motor-Related Processing Influences Verbal Memory." *Consciousness and Cognition* 21 (3): 1563–1570. doi:10.1016/j.concog.2012.07.006.

Madan, Christopher R., and Anthony Singhal. 2013. "Introducing TAMI: An Objective Test of Ability in Movement Imagery." *Journal of Motor Behavior* 45 (2): 153–166. doi:10.1080/00222895.2013.763764.

Madan, Christopher R., and Anthony Singhal. 2014. "Improving the TAMI for Use with Athletes." *Journal of Sports Sciences* 32 (14): 1351–1356. doi:10.1080/02640414.2014.889847.

Madan, Christopher R., and Anthony Singhal. 2015. "No Sex Differences in the TAMI." Cognitive Processing 16 (2): 203–209. doi:10.1007/s10339-014-0644-y.

Mahon, Bradford Z., and Alfonso Caramazza. 2008. "A Critical Look at the Embodied Cognition Hypothesis and a New Proposal for Grounding Conceptual Content." *Journal of Physiology, Paris* 102 (1–3): 59–70. doi:10.1016/j.jphysparis.2008.03.004.

Marks, David. F. 1973. "Visual Imagery Differences in the Recall of Pictures." *British Journal of Psychology* 64:17–24.

McIsaac, Heather K., and Eric Eich. 2004. "Vantage Point in Traumatic Memory." *Psychological Science* 15 (4): 248–253. doi:10.1111/j.0956-7976.2004.00660.x.

McMillan, Rebecca L., Scott Barry Kaufman, and Jerome L. Singer. 2013. "Ode to Positive Constructive Daydreaming." *Frontiers in Psychology* 4 (September): 626. doi:10.3389/fpsyg.2013.00626.

Milton, John, Ana Solodkin, Petr Hlustík, and Steven L. Small. 2007. "The Mind of Expert Motor Performance Is Cool and Focused." *NeuroImage* 35 (2): 804–813. doi:10.1016/j.neuroimage.2007.01.003.

Moran, Aidan. 2002. "In the Mind's Eye." *Psychologist* 15 (8): 414–415.

Moran, Aidan. 2012. "Thinking in Action: Some Insights from Cognitive Sport Psychology." *Thinking Skills and Creativity* 7 (2): 85–92. doi:10.1016/j.tsc.2012.03.005.

Moran, Aidan, Mark Campbell, Paul Holmes, and Tadhg MacIntyre. 2012. "Mental Imagery, Action Observation and Skill Learning." In *Skill Acquisition in Sport: Research, Theory and Practice*, edited by N. Hodges and M. A. Williams, 94–111. London: Routledge.

Moran, Aidan, Aymeric Guillot, Tadhg MacIntyre, and Christian Collet. 2012. "Re-Imagining Motor Imagery: Building Bridges between Cognitive Neuroscience and Sport Psychology." *British Journal of Psychology* 103 (2): 224–247. doi:10.1111/j.2044-8295.2011.02068.x.

Moran, Aidan, and Tadhg MacIntyre. 1998. "'There's More to an Image than Meets the Eye': A Qualitative Study of Kinaesthetic Imagery among Elite Canoe-Slalomists." *Irish Journal of Psychology* 19 (4): 406–423. doi:10.1080/03033910.1998.10558203.

Morris, Tony, Michael Spittle, and Anthony P. Watt. 2005. *Imagery in Sport*. Champaign, IL: Human Kinetics.

Munzert, Jörn, Britta Lorey, and Karen Zentgraf. 2009. "Cognitive Motor Processes: The Role of Motor Imagery in the Study of Motor Representations." *Brain Research Reviews* 60 (2): 306–326. doi:10.1016/j.brainresrev.2008.12.024.

Newell, Allen, Herbert Alexander Simon. 1972. *Human Problem Solving*. Vol. 104. Englewood Cliffs, NJ: Prentice-Hall.

Nikulin, Vadim V., Friederike U. Hohlefeld, Arthur M. Jacobs, and Gabriel Curio. 2008. "Quasi-Movements: A Novel Motor-Cognitive Phenomenon." *Neuropsychologia* 46 (2): 727–742. doi:10.1016/j.neuropsychologia.2007.10.008.

Nishida, T., A, Katube, K. Inomata, Y. Okazawa, M. Ito, S. Kayama, K. Tsuru- hara, and Y. Yoshizawa. 1986. "A New Test for Controllability of Motor Imagery: The Examination of Its Validity and Reliability." *Japan Journal of Physical Education* 31:13–22.

Nordin, Sanna M., and Jennifer Cumming. 2005. "Professional Dancers Describe Their Imagery: Where, When, What, Why, and How." *Sport Psychologist* 19 (4): 395–416. doi:10.1123/tsp.19.4.395.

Olsson C. J., and Lars Nyberg. 2010. "Motor Imagery: If You Can't Do It, You Won't Think It." *Scandinavian Journal of Medicine and Science in Sports* 20 711–715 10.1111/j.1600-0838.2010.01101.x

Olsson, C. J., and Lars Nyberg. 2011. "Brain Simulation of Action May Be Grounded in Physical Experience." *Neurocase* 17 (6): 501–505. doi:10.1080/13554794.2010.547504.

Park, Sohee, and Stephen M. Kosslyn. 1990. "Imagination." In *Reflections on "The Principles of Psychology": William James after a Century*, edited by G. Johnson and T. B. Henley, 183–196. Hillsdale, NJ: Erlbaum.

Parsons, Larry M. 1987. "Imagined Spatial Transformation of One's Body." *Journal of Experimental Psychology: General* 116:172–191.

Pavlova, Marina A. 2012. "Biological Motion Processing as a Hallmark of Social Cognition." *Cerebral Cortex* 22 (5): 981–995. doi:10.1093/cercor/bhr156.

Pearson, Joel, and Stephen M. Kosslyn. 2013. “Mental Imagery.” *Frontiers in Psychology* 4 (April): 198. doi:10.3389/fpsyg.2013.00198.

Perky, Cheves West. 1910. “An Experimental Study of Imagination.” *American Journal of Psychology* 21 (3): 422–452. doi:10.2307/1413350.

Peters, M., B. Laeng, K. Latham, M. Jackson, R. Zaiyouna, and C. Richardson. 1995. “A Redrawn Vandenberg and Kuse Mental Rotations Test: Different Versions and Factors That Affect Performance.” *Brain Cognition* 28 (1): 39–58.

Pylyshyn, Zenon W. 2002. “Mental Imagery: In Search of a Theory.” *Behavioral and Brain Sciences* 25 (2): 157–182; discussion 182–237. doi:10.1017/s0140525x02000043.

Rizzolatti, G., L. Fogassi, and V. Gallese. 2001. “Neurophysiological Mechanisms Underlying the Understanding and Imitation of Action.” *Nature Reviews: Neuroscience* 2 (9): 661–670.

Roberts, R., N. Callow, L. Hardy, D. Markland, and J. Bringer. 2008. “Movement Imagery Ability: Development and Assessment of a Revised Version of the Vividness of Movement Imagery Questionnaire.” *Journal of Sport and Exercise Psychology* 30:200–221.

Rosenbaum, David A. 2005. “The Cinderella of Psychology: The Neglect of Motor Control in the Science of Mental Life and Behavior.” *American Psychologist* 60 (4): 308–317. doi:10.1037/0003-066x.60.4.308.

Saimpont, Arnaud, Francois Malouin, B. Tousignant, and Phillip L. Jackson. 2012. “The Influence of Body Configuration on Motor Imagery of Walking in Younger and Older Adults.” *Neuroscience* 222 (October): 49–57. doi:10.1016/j.neuroscience.2012.06.066.

Schack, Thomas, Kai Essig, Cornelia Frank, and Dirk Koester. 2014. “Mental Representation and Motor Imagery Training.” *Frontiers in Human Neuroscience* 8:328. doi:10.3389/fnhum.2014.00328.

Shapiro, Lawrence. 2011. *Embodied Cognition*. London: Routledge.

Shapiro, Lawrence, and Shannon Spaulding (this volume). “Embodied Cognition and Sport.” In *Handbook of Embodied Cognition and Sport Psychology*, edited by Massimiliano Cappuccio. Cambridge, MA: MIT Press.

Sheehan, Peter Winston 1967. “A Shortened Form of Betts’ Questionnaire upon Mental Imagery.” *Journal of Clinical Psychology* 23 (3): 386–389.

Shepard, Roger N., and Jackie Metzler. 1971. “Mental Rotation of Three-Dimensional Objects.” *Science* 171 (3972): 701–703. doi:10.1126/science.171.3972.701.

Slepian, Michael L., Max Weisbuch, Nicholas O. Rule, and Nalini Ambady. 2011. “Tough and Tender: Embodied Categorization of Gender.” *Psychological Science* 22 (1): 26–28.

Stock, Armin, and Claudia Stock. 2004. “A Short History of Ideo-Motor Action.” *Psychological Research* 68 (2–3): 176–188. doi:10.1007/s00426-003-0154-5.

Suinn, Richard M. 1972. "Behavior Rehearsal Training for Ski Racers." *Behavior Therapy* 3 (3): 519–520. doi:10.1016/s0005-7894(72)80191-6.

Suinn, Richard M. 1997. "Mental Practice in Sport Psychology: Where Have We Been, Where Do We Go?" *Clinical Psychology: Science and Practice* 4 (3): 189–207. doi:10.1111/j.1468-2850.1997.tb00109.x.

Vandell, Roland A., Robert A. Davis, and Herbert A. Clugston. 1943. "The Function of Mental Practice in the Acquisition of Motor Skills." *Journal of General Psychology* 29 (2): 243–250. doi:10.1080/00221309.1943.10544442.

Voyer, D. 2011. "Time Limits and Gender Differences on Paper-and-Pencil Tests of Mental Rotation: A Meta-Analysis." *Psychonomic Bulletin & Review*, 18:267–277. doi:10.3758/s13423-010-0042-0.

Webb, Christine E., Maya Rossignac-Milon, and E. Tory Higgins. 2017. "Stepping Forward Together: Could Walking Facilitate Interpersonal Conflict Resolution?" *American Psychologist* 72 (4): 374–385.

Wilson, Andrew D., and Sabrina Golonka. 2013. "Embodied Cognition Is Not What You Think It Is." *Frontiers in Psychology* 4 (February): 58. doi:10.3389/fpsyg.2013.00058.

Wilson, Margaret. 2002. "Six Views of Embodied Cognition." *Psychonomic Bulletin and Review* 9 (4): 625–636. doi:10.3758/bf03196322.

Wraga, Maryjane, and Stephen M. Kosslyn. 2002. "Imagery." In *Encyclopedia of Cognitive Science* 2, 466–470. London: Nature Publishing Group.

Wraga, Mary-Jane, and Stephen M. Kosslyn. 2006. "Imagery." In *Encyclopedia of Cognitive Science* 2, edited by Lynn Nadel, 466–470. Hoboken, NJ: John Wiley and Sons.