1 Imagery interventions in sport

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Introduction

Imagery is described as an experience that mimics real experience, and involves using a combination of different sensory modalities in the absence of actual perception. White and Hardy explained that "we can be aware of 'seeing' an image, feeling movements as an image, or experiencing an image of smell, taste or sounds without experiencing the real thing" (1998: 389), whereas Moran defined imagery as "perception without sensation" (2004: 133). Another commonality among definitions is the notion that individuals are self-aware and conscious during the imagery experience (Richardson, 1969). For example, White and Hardy distinguished imagery from dreaming because the individual is awake and conscious when imaging.

Among sport performers and coaches, imagery is a popular and well-accepted strategy for enhancing various aspects of performance. The importance of this strategy is reflected in anecdotal reports of successful athletes. For example, Ronaldinho, a midfielder for FC Barcelona and one of the world's best footballers, eloquently described his use of imagery before the World Cup in 2006 in an article appearing in the *New York Times Sports Magazine*:

> When I train, one of the things I concentrate on is creating a mental picture of how best to deliver that ball to a team-mate, preferably leaving him alone in front of the rival goalkeeper. So what I do, always before a game, always, every night and every day, is try and think up things, imagine plays, which no one else will have thought of, and to do so always bearing in mind the particular strengths of each team-mate to whom I am passing the ball. When I construct those plays in my mind I take into account whether one team-mate likes to receive the ball at his feet, or ahead of him; if he is good with his head, and how he prefers to head the ball; if he is stronger on his right or his left foot. That is my job. That is what I do. I imagine the game.
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Descriptive research also suggests that imagery is frequently used by the best athletes. In their study of the elements of success, Orlick and Partington (1988) found that 99 per cent of Canadian Olympic athletes surveyed reported using imagery as a preparation strategy. Furthermore, higher-level athletes or those with more experience typically report greater use of the strategy than their lower-level or less-experienced counterparts (e.g. Barr and Hall, 1992; Cumming and Hall, 2002a, 2002b; Hall *et al.*, 1998; Salmon *et al.*, 1994).

Not surprisingly, imagery has become a widely researched topic within the field of sport psychology as evidenced by numerous published studies, recent book chapters (e.g. Callow and Hardy, 2005; Moran, 2004; Murphy *et al.*, in press), an entire book (Morris *et al.*, 2005), and the introduction of a journal devoted to publishing imagery research in the physical domain (*Journal of Imagery Research in Sport and Physical Activity*). The aim of our chapter is to complement this body of literature with a review focusing specifically on imagery interventions. The emphasis will be on contemporary frameworks guiding such work with particular reference to the applied model of imagery use (Martin *et al.*, 1999) and the PETTLEP model (Holmes and Collins, 2001). We will also discuss how recent advancements in the cognitive neurosciences may inform intervention design and measurement with recommendations made for best practice.

Key terms

A useful starting point in any review is to clarify the meaning of key terms frequently used in the literature. Indeed, there has been confusion resulting from the interchangeable use of "visualisation" and "mental practice" with imagery. Several authors have argued that these terms are referring to related but distinctly different constructs (e.g. Morris *et al.*, 2005; Murphy and Martin, 2002). While visualisation denotes a particular sensory modality (i.e. vision), imagery encompasses all different "quasi-sensory or quasi-perceptual experiences" (Richardson, 1969: 2). In research, imagery is the preferred and most commonly used term since athletes' images are not limited to just those experienced in the mind's eye (e.g. Munroe *et al.*, 2000). Murphy and Martin (2002) have explained that imagery should also be carefully distinguished from mental practice; that is, imagery is a specific mental process that can be mentally practised. However, mental practice does not necessarily involve imagery but can also refer to other types of mental processes including self-talk and modelling.

The most recent debate addresses the conceptual difference between imagery type, function and outcome (for a more detailed discussion, see Murphy *et al.*, in press; Short *et al.*, 2006). The term "imagery type" has been used to describe both the content of an athlete's imagery (e.g. imaging oneself perfectly executing a skill) and the function or purpose that imagery is serving (e.g. skill refinement) leading to uncertainty among authors. As an illustration, items on the Sport Imagery Questionnaire (SIQ; Hall *et al.*, 1998) were originally described as measuring imagery content (Moritz *et al.*, 1996), then later referred to them as functions (Hall *et al.*, 1998, 2005). Short *et al.* (2006) noted that this shift in meaning of the SIQ items has led to the synonymous use of "type" and "function". For example, Martin *et al.* referred to these as interchangeable terms in their review of literature and development of an applied model. Imagery type is mostly referred to as "the function or purpose that imagery is serving" (1999: 249); but content is alluded to when the authors predict that cognitive imagery types might serve a motivational function by enabling athletes to focus in competitive settings. Hall (2001) has also explained that knowing something about the content of an athlete's imagery does not necessarily indicate what function this imagery is serving. To continue with the above example, an athlete might describe imaging the perfect execution of a skill in a competitive situation. Three possible functions of this image are skill refinement, motivation and self-efficacy enhancement. The athlete might be using the imagery for one, two or all three of these functions. Adding to the confusion is that other authors have used "type" to refer specifically to the sensory modality employed (Driediger *et al.*, 2006; Munroe *et al.*, 2000; Munroe-Chandler *et al.*, 2007). To resolve the conundrum, Murphy *et al.* (in press) proposed that *imagery type* should be reserved for describing the content of an image (i.e. "what"), whereas *imagery function* should denote the purpose or reason for employing the image (i.e. "why"). Finally, *imagery outcome* should describe the result of the imagery (e.g. improved skill performance, increased motivation, higher levels of self-efficacy).

With these definitions in mind, the items of the SIQ would probably be more appropriately referred to as imagery types that can be used for different cognitive and motivational functions by athletes (Murphy *et al.*, in press; Short *et al.*, 2006). We will return to this particular concept later in the chapter when reviewing literature surrounding the applied model of imagery use. It is important to point out, however, that researchers should be careful in their employment of the term "use" when describing athletes' imagery, because "use" implies that athletes are deliberately engaging in the strategy when this is not necessarily the case. Indeed, there is evidence to suggest that performers will experience some amount of imagery in a spontaneous manner (Evans *et al.*, 2004; Nordin and Cumming, 2005b; Nordin *et al.*, 2006). For this reason, Nordin and Cumming (2006) favoured terminology such as "imaging" rather than "use of imagery" when describing dancers' imagery in the development of the Dance Imagery Questionnaire (DIQ).

Review of the literature

The early imagery research was dominated by experimental designs comparing the effectiveness of imagery alone to physical practice, no practice, or varying combinations of imagery and physical practice, for the acquisition and performance of motor skills (for reviews, see Driskell *et al.*, 1994; Feltz and Landers, 1983; Hall, 2001; Jones and Stuth, 1997). Effect sizes reported in the three different meta analyses carried out on this literature have ranged from small (0.26; Driskell *et al.*, 1994) to large (0.66; Hinshaw, 1991) in magnitude. These findings suggest that imagery is an effective means of improving performance, but is less effective than physical practice. Several moderators were also identified as influencing imagery effectiveness to help shed light on previous discrepant findings. Variables considered as moderators included the type of task being imaged, the experience level of the performer, the duration and timing of the imagery practice, and the individual's ability to generate and control vivid images. Less commonly reported were field-based imagery interventions specifically designed to enhance athletic performance. The results of these studies were equivocal, with some reporting significant improvements compared to a control group (e.g. Grouios, 1992; Study 1 of Hardy and Callow, 1999; Isaac, 1985), while others reported no significant differences (e.g. Mumford and Hall, 1985; Rodgers *et al.*, 1991), or mixed findings across performance variables (e.g. Blair *et al.*, 1993; Burhans *et al.*, 1998). Unfortunately, these studies varied greatly in their design, from the duration of the intervention to the level of athlete involved, making it difficult to draw comparisons and pinpoint the reasons underlying the equivocal findings. However, several authors have raised consistent concerns with the methodology of imagery intervention studies that may help to understand these results (e.g. Goginsky and Collins, 1996; Jones and Stuth, 1997; Murphy and Jowdy, 1992). Callow and Hardy (2005) summarised these concerns as being a failure to take confounding variables into account (e.g. imagery ability), employing flawed research designs (e.g. lack of manipulation checks to verify if the participants are imaging as instructed), the lack of empirically tested theories underpinning the intervention, and not clearly differentiating the functions of imagery.

Over the last decade, there has been a surge in the number of published cross-sectional studies, along with a growing number of field-based interventions. Researchers have examined imagery as part of a mental-skills training package, and generally found significant improvements to performance and psychological factors such as the interpretations of the symptoms associated with competition anxiety (e.g. Hanton and Jones, 1999; Mamassis and Doganis, 2004; Sheard and Golby, 2006). Performance has been less frequently measured when imagery is the only mental skill delivered in an intervention. The majority of these studies have instead focused on the improvements found to self-confidence (e.g. Callow and Waters, 2005), or related constructs of self-efficacy (e.g. Jones *et al.*, 2002) and collective efficacy (e.g. Munroe-Chandler and Hall, 2004). When performance is measured, however, the results have consistently shown the benefits of using imagery (e.g. Smith *et al.*, 2007). Most promising is the trend for recent research to carry out methodologically sound and theoretically based interventions. This task has been made much easier thanks to the introduction of two models to the imagery literature that can be used separately or in conjunction with each other to guide interventions. Each of these models will now be discussed in turn.

The applied model of imagery use

The applied model of imagery use (Martin *et al.*, 1999) describes the manner in which athletes can use imagery to achieve a variety of cognitive, affective and behavioural outcomes. The sport situation, the types of imagery used and imagery ability are considered as three factors that contribute to the effectiveness of an imagery intervention. At the heart of the model is the notion that "what you see is what you get"; in other words, imagery content should correspond with the intended outcomes. For instance, Moritz *et al.* (1996) have suggested that an athlete who wishes to develop, maintain or regain sport confidence (i.e. function) should image being confident (i.e. content). Furthermore, the nature of the sport situation (e.g. training, competition and rehabilitation) should be considered for imagery to have positive effects. To continue with the above example, an athlete might image being confident during a period of rehabilitation to regain the confidence lost due to being injured. Finally, imagery ability will likely influence the impact of an imagery intervention such that better imagers will benefit more. Altogether, the model proposes that athletes should use the appropriate type of imagery in the given sport situation to help them to achieve their goals.

Imagery types

There are five types of imagery mentioned in the model. However, Martin *et al.* (1999) recognised that these do not constitute an exhaustive list and further imagery types may be added as they are identified in the literature. These types stem from Paivio's (1985) analytical framework and were conceptualised further by Hall *et al.* (1998) while developing the SIQ. Paivio initially proposed that imagery serves both cognitive and motivational functional roles, with each operating at specific and general levels. Hall *et al.* later suggested that motivational general (MG) imagery was best understood when divided into arousal and mastery subtypes resulting in the following:

- cognitive specific (CS): imagery of sport skills or rehabilitation exercises (e.g. running style, penalty flick in field hockey).
- cognitive general (CG): imagery of strategies, game plans and routines (e.g. man-to-man defence, give-and-go offence, pre-shot routine).
- motivational specific (MS): imagery of specific goals and goal-oriented behaviour (e.g. achieving a personal best, winning a medal).
- motivational general arousal (MGA): imagery of somatic and emotional experiences (e.g. stress, arousal, anxiety and excitement).
- motivational general mastery (MGM): imagery of coping and mastering challenging situation (e.g. staying focused and positive after making an error, being confident in an important competition).

Employing the SIQ, it has been consistently found that athletes image all five types, but tend to report a higher frequency of motivational as compared to cognitive images (e.g. Cumming and Hall, 2002a; Hall *et al.*, 1998; Moritz *et al.*, 1996; Munroe *et al.*, 1998; Vadocz *et al.*, 1997). Martin *et al.* (1999) consider the imagery types to be functionally orthogonal. That is, athletes might use these imagery types alone or in combination with each other. It is important to point out that, although these labels are intended to reflect imagery functions, they have been historically explained in terms of what athletes are imaging (e.g. Hall *et al.*, 1998, 2005; Martin *et al.*, 1999; Munroe *et al.*, 2000). Content and function were therefore considered as one and the same in the development of the model, although many authors have now argued that this is not necessarily the case (e.g. Abma *et al.*, 2002; Callow and Hardy, 2001; Hall, 2001; Hall *et al.*, 1998; Murphy *et al.*, in press; Nordin and Cumming, 2005a, Short *et al.*, 2002, 2004a, 2006; Vadocz *et al.*, 1997). We will return to this point later in the chapter when discussing the mixed findings of the applied model to date. For clarity, we have therefore chosen to separate type and function in our description of the model.

Recent qualitative enquiries in dance (Hanrahan and Vergeer, 2000; Nordin and Cumming, 2005b), exercise (Giacobbi *et al.*, 2003; Short *et al.*, 2004b), sport (Calmels *et al.*, 2003) and injury rehabilitation settings (Driediger *et al.*, 2006; Evans *et al.*, 2006; Vergeer, 2006) suggest that other types of imagery exist. Body-related images, in addition to those considered to be MGA imagery, are one such example. These include anatomical images related to posture and alignment (Hanrahan and Vergeer, 2000; Nordin and Cumming, 2005b), health- and appearance-related images (Gammage *et al.*, 2000; Giacobbi *et al.*, 2003; Nordin and Cumming, 2005b), and images of the internal physiological processes of healing (Driediger *et al.*, 2006; Evans *et al.*, 2006; Hanrahan and Vergeer, 2000). To illustrate the latter, an injured badminton player interviewed by Driediger *et al.* said:

> I would try to imagine what the tear looked like and I think about how it feels and how it's going to heal and try to think about how it's coming together while it's healing, or during the rehabilitation process.
>
> (2006: 266)

Such healing images are captured on a sub-scale of the Athletic Injury Imagery Questionnaire-2 (AIIQ-2; Sordoni *et al.*, 2002), and are positively associated with self-efficacy (Sordoni *et al.*, 2002) and satisfaction with the rehabilitation experience (Law *et al.*, 2006). Both exercisers and dancers have reported appearance-related images. For example, female aerobic exercisers interviewed by Giacobbi *et al.* said "I imagine myself being toned" and "I see myself losing weight" (2003: 168). Interestingly, this is the most frequently reported imagery type by exercisers, and positively associated with self-reported exercise behaviour (Gammage *et al.*, 2000; Hausenblas *et al.*, 1999) and behavioural intention (Rodgers *et al.*, 2001).

There is also growing interest in kinaesthetic imagery, which Callow and Waters have defined as "imagery involving the sensations of how it feels to perform an action, including the force and effort involved in movement and balance, and spatial location (either of a body part or piece of sports equipment)" (2005: 444–445). Munroe *et al.* (2000) previously noted that the varsity athletes interviewed in their study frequently mentioned kinaesthetic images. Furthermore, an athlete's ability to kinaesthetically image has been positively associated with state confidence (Hardy and Callow, 1999; Moritz *et al.*, 1996; Monsma and Overby, 2004) and negatively associated with the intensity of cognitive anxiety symptoms (Monsma and Overby, 2004). Finally, Hardy and Callow (1999) found the combination of visual and kinaesthetic imagery led to greater skill acquisition and performance benefits than visual imagery alone for expert rock climbers learning four ten-move boulder problems (Experiment 3). Altogether, these studies suggest that kinaesthetic imagery is a particularly important type of imagery for athletes. Interestingly, Martin *et al.* (1999) suggested that kinaesthetic images (and other sensory modalities) might eventually be considered in the model, but felt that there was insufficient evidence at that time to warrant inclusion. Since the model has been published, Callow and Waters have carried out a single-subject multiple baseline study with three male professional flat-race horse jockeys to examine whether kinaesthetic imagery could improve state sport confidence. In line with their rationale that kinaesthetic imagery could serve as a form of performance accomplishment, a significant increase in state sport confidence was found for two of the three participants following a kinaesthetic imagery intervention. The authors consequently concluded that images, which match the actual sensations of successful performance, could be a useful tool for enhancing confidence.

Other images worth mentioning are those of an artistic nature, which are relevant to aesthetic sport athletes whose artistic ability is judged in competition. Professional dancers interviewed by Nordin and Cumming (2005b) reported images of characters and roles including behaviours, emotions and qualities that they might want to emphasize in a piece. The role and movement quality imagery sub-scale of the DIQ measures these images along with expression, movement quality (e.g. harmony between movements and music) and metaphors (i.e. images depicting actions and sensations that are not necessarily objectively possible). In a follow-up study, Nordin and Cumming (in press, a) found that aesthetic sport athletes (e.g. artistic gymnasts, equestrian vaulters) reported using role and movement imagery, but not to the same extent as dancers sampled in the same study. Nevertheless, the findings suggest that imagery related to aesthetic expression could provide the basis of an imagery intervention aimed at enhancing the artistry of aesthetic sport athletes. Metaphorical images may also be helpful in communication, to identify and express thoughts and emotions, assist focus and concentration, maintain confidence and aid relaxation (Murphy *et al.*, in press). Furthermore, direct effects on performance have been found following the use of metaphorical imagery with dancers. Sawada *et al.* (2002) carried out an intervention with 60 children, and showed that children who received metaphorical instructions performed a short dance sequence more accurately than children who had received either verbal descriptions of the movements or no instruction. Improvements to the performance of certain dance moves have also been reported following a metaphorical imagery intervention with adult dancers (Hanrahan and Salmela, 1990; Hanrahan *et al.*, 1995).

Imagery functions

There are a multitude of reasons why athletes engage in imagery (e.g. Munroe *et al.*, 2000; Nordin and Cumming 2005a; for reviews, see Murphy and Martin, 2002; Murphy *et al.*, in press). The majority of these fall broadly into the cognitive and functional roles proposed by Paivio (1985). *Cognitive reasons* include learning and improving performance, memorising, planning and strategising, and improving understanding. When examined at the specific and general levels, the CS function pertains specifically to skill development (i.e. to work on technique and to make changes) and performance (i.e. to perform as well as possible in any given situation), whereas the CG function similarly describes strategy development and execution (Munroe *et al.*, 2000). *Motivational reasons* include enhancing motivation, changing thoughts and emotions, and regulating physiological responses. Munroe *et al.* described the MS function as being used by athletes to understand what it takes to achieve process and outcome goals. The MGA function pertains to the regulation of emotions and activation levels (e.g. to psych up, maintain composure, or relax). Finally, the MGM function is used to stay focused, confident, positive and mentally tough (i.e. work through difficult situations and deal with adversity). *Healing reasons* have also emerged as a function in the injury-rehabilitation literature (Calmels *et al.*, 2003; Driediger *et al.*, 2006; Nordin and Cumming, 2005b). For example, the athletes interviewed by Driediger *et al.* reported using imagery to aid in the healing process, for pain management and the prevention of injury. In addition, dancers interviewed by Nordin and Cumming (2005b) used imagery to rejuvenate and revitalise as well as for spiritual healing. Finally, *artistic reasons* for using imagery may be to communicate with one's audience, to add meaning, to enhance the quality of one's movements and to choreograph a sequence or routine (Murphy *et al.*, in press).

Imagery outcomes

The model suggests three categories of outcomes that can be achieved through imagery: (a) facilitating the learning and performance of skills and strategies; (b) modifying cognitions; and (c) regulating arousal and competitive anxiety. Moreover, the content of an athlete's images will systematically determine what result has been achieved (Short *et al.*, 2006). Recall that the applied model is based on the premise that imagery type will lead to a harmonious outcome. For example, a figure skater trying to improve their technique of a salchow jump (CS imagery function) may image the successful take-off and landing of the jump (CS imagery content). If effective, the result of such imagery would then be qualitative improvements in performance and increased jump consistency (CS outcome). Research has generally supported this idea by demonstrating that skill-based images will lead to improved skill performance (e.g. Durand *et al.*, 1997; Hall *et al.*, 1994; Nordin and Cumming, 2005a; for a review, see Driskell *et al.*, 1994; Hall, 2001), and are more effective than goal-based imagery for performance improvements of beginner runners (MS content;

Burhans *et al.*, 1988), arousal-based imagery for a strength task (MGA content; Murphy *et al.*, 1988), or confidence-based imagery for a sit-up task (MGM content; Lee, 1990).

Skill-based images have also resulted in outcomes beyond those predicted by the "what you see is what you get" principle (e.g. Anshel and Wrisberg, 1993; Calmels *et al.*, 2004b; McKenzie and Howe, 1997; Martin and Hall, 1995; Nordin and Cumming, 2005a). Imaging the "perfect stroke" led to significantly greater voluntary practice time of a golf-putting task (inferring greater motivation) than either the performance + outcome imagery group or the no-imagery control group (Martin and Hall, 1995). Anshel and Wrisberg (1993) found that tennis players' imagery of performing mechanically correct serves resulted in increased somatic (i.e. heart rate) and cognitive arousal. Both McKenzie and Howe (1997) and Nordin and Cumming (2005a) reported increased self-efficacy following imagery of dart throws. Finally, the CS sub-scale of the SIQ has been positively associated with increased trait confidence (Abma *et al.*, 2002) and facilitative interpretations of the symptoms associated with cognitive and somatic anxiety (Fish *et al.*, 2004).

Less research attention has been given to images of strategies, routines and game plans. Indeed, when the applied model was initially published, evidence in support of CG imagery was mainly anecdotal in nature or case study reports (e.g. Fenker and Lambiotte, 1987; White and Hardy, 1998). There have been a few studies to show that imagery of skills sequenced together led to improvements in the performance of that sequence when compared to a control group (Blair *et al.*, 1993; Hardy and Callow, 1999). Only recently have interventions been undertaken to examine strategy-based images, and this research has led to mixed findings. Jordet (2005) used a single-case intervention design to show the effects of an intervention consisting of skill and strategy images with elite football players. He found improved exploratory visual activity for two out of the three players involved. By comparison, imaging the execution of football strategies did not lead to significantly improved implementation of these strategies in game situations for players on an Under-13 team (Munroe-Chandler *et al.*, 2005). The CG sub-scale of the SIQ has also been positively associated with state and trait sport confidence (Abma *et al.*, 2002; Callow and Hardy, 2001).

With respect to goal-based images, Martin and Hall (1995) found that imaging "a perfect stroke" combined with "the golf ball rolling across the green and into the hole" (performance + outcome imagery) led to significantly greater number of balls holed compared to imaging the perfect stroke only or control group. Moreover, participants in this condition also set higher goals for themselves and adhered more to their training regime, but did not demonstrate greater voluntary practice behaviour. MS imagery has also been positively associated with achievement goals (Cumming *et al.*, 2002), state and trait sport confidence (Abma *et al.*, 2002; Callow and Hardy, 2001; Evans *et al.*, 2004), and self-efficacy (Mills *et al.*, 2000).

Images of somatic and emotional experiences such as oneself competing in a race have resulted in measurable physiological changes in heart rate and respiration (Gallego *et al.*, 1996; Hecker and Kaczor, 1988). Martin *et al.* (1999) explained that MGA images contain necessary information about the physiological and emotional response of the performer (termed "response propositions"; Lang, 1977, 1979) to bring about these measurable increases in activation. Furthermore, Murphy *et al.* (1988) found that images of anger and fear prior to a strength task led to increased reports of feeling anxious, whereas images of being relaxed were associated with decreased levels of state anxiety intensity in another study (Murphy and Woolfolk, 1987). The MGA sub-scale of the SIQ, which describes images of being excited, stressed, psyched-up and anxious, has been associated with a greater intensity of symptoms associated with cognitive and somatic anxiety (Monsma and Overby, 2004; Vadocz *et al.*, 1997). Finally, Cumming *et al.* (2007) carried out a comparison of different forms of MGA imagery content (i.e. relaxation images, psyching-up images and competitive anxiety images), MGM imagery, and a combination of MGA and MGM imagery (termed "coping imagery" in this study) on heart rate response and self-reported psychological states. A total of 40 competitive individual sport athletes imaged five different imagery scripts, delivered in a counter-balanced order, and describing the immediate moments before performing in a hypothetical competition. As expected, only imagery scripts that contained somatic response information (MGA psyching up imagery, MGA anxiety imagery and coping imagery) led to significant increases in heart rate and anxiety intensity.

Similar to the above imagery types, associations have been found between MGA images and mastery cognitions. Certain SIQ studies report MGA imagery to be positively associated with state sport confidence (Moritz *et al.*, 1996), trait sport confidence (Abma *et al.*, 2002) and self-efficacy (Mills *et al.*, 2000). Other studies, however, have found a negative relationship to exist (Callow and Hardy, 2001; Monsma and Overby, 2004). On the surface, these contradictory findings may seem a little puzzling. However, they do make sense from the point of view of Bandura's (1997) self-efficacy theory. More specifically, MGA imagery may fulfil a source of self-efficacy called "physiological and affective states" by enabling individuals to experience optimal activation levels. If the content of imagery does not match the desired activation level, self-efficacy may lower. In support, Cumming *et al.* (2007) found that MGA anxiety imagery resulted in less self-confidence and more debilitative interpretations of symptoms associated with pre-competition anxiety than MGA psyching up imagery, MGM imagery and coping imagery. Lower levels of confidence were also reported after MGM relaxing imagery. These findings led the authors to suggest that athletes should be careful to use the aspect of MGA imagery that will lead to their desired activation level, and images of being anxious in competition without corresponding feelings of mastery may be problematic for certain athletes. By comparison, combining MGA and MGM content allows the athlete to simultaneously experience high levels of anxiety and self-confidence. Termed "confident coping", Jones and Hanton (2001) have suggested that this psychological state will enable athletes to view the symptoms associated with competitive anxiety in a more facilitative manner. Along similar lines, an intervention combining both MGA and MGM imagery led to lower levels of perceived stress and increased self-efficacy before and during a rock-climbing task (Jones *et al.*, 2002).

Finally, numerous SIQ studies have shown the MGM sub-scale to be positively associated with state sport confidence (Callow and Hardy, 2001; Fish *et al.*, 2004; Monsma and Overby, 2004; Mortiz *et al.*, 1996; Vadocz *et al.*, 1997), trait sport confidence (Abma *et al.*, 2002), self-efficacy (Beauchamp *et al.*, 2002; Mills *et al.*, 2000) and collective efficacy (Shearer *et al.*, 2007). Experimentally designed research has also found that mastery images lead to increased self-efficacy (Feltz and Riessinger, 1990) and state confidence (Cumming *et al.*, 2007), whereas intervention studies have reported improvements to state confidence (Callow *et al.*, 2001) and collective efficacy (Munroe-Chandler and Hall, 2004). More recently, Nicholls *et al.* (2005) carried out an MGM imagery intervention to enhance the flow experiences of high-performance golfers. Employing a single-subject replication reversal design, three of the four participants reported increased intensity of flow states, and all four reported increased frequency of flow states and percentage of successful golf shots, albeit these changes were relatively small in nature. Other studies have also shown a direct association between MGM imagery and better performance (Beauchamp *et al.*, 2002; Nordin and Cumming, 2005a; Short *et al.*, 2002), lower levels of cognitive and somatic anxiety intensity (Cumming *et al.*, 2007; Monsma *et al.*, 2004), and more facilitative anxiety interpretations (Cumming *et al.*, 2007).

Altogether, there seems to be some amount of congruence between the content of athletes' images and the outcome of their imagery that is consistent with the applied model's "what you see is what you get" principle. There is growing evidence, however, which shows that imagery will offer more results beyond what meets the eye (Nordin and Cumming, 2005a). More specifically, a number of investigations have found that one imagery type can be related to several outcomes (Callow and Waters, 2005; Calmels *et al.*, 2003; Evans *et al.*, 2004; Nicholls *et al.*, 2005; Nordin and Cumming, 2005a, in press b; Short *et al.*, 2002, 2004a). The relationships between different imagery types and outcomes therefore appear more complex than initially considered by the applied model. If imagery type were replaced by function, however, the predictions would likely hold more consistently. Instead of content systematically determining the outcomes, it would instead be the function of that imagery. To explain their findings, for example, Callow and Hardy (2001) stated that it might not be what is being imaged that influences confidence, but rather the function that imagery is serving. As long as the imagery is effective, there would then likely be a match between the athlete's reason for imaging and the outcome achieved. The challenge then becomes to select the appropriate content that will serve the intended function, which is an issue that we will address in the next section.

In addition to the three categories of outcomes outlined, the model could be expanded to include outcomes related to the imagery process, injury rehabilitation and, unexplored as of yet, artistry and other more aesthetic aspects of performance. Several studies have already found significant increases in the frequency of athletes' imagery following involvement in an imagery intervention (Callow *et al.*, 2001; Cumming *et al.*, 2004; Cumming and Ste-Marie, 2001; Evans *et al.*, 2004; Munroe-Chandler *et al.*, 2005; Rodgers *et al.*, 1991). Imagery ability has also been found to improve (Calmels *et al.*, 2004b; Cumming and Ste-Marie, 2001; Rodgers *et al.*, 1991) and imagery sessions found to be more systematic and detailed (Evans *et al.*, 2004; Rodgers *et al.*, 1991). With respect to the rehabilitation process, Cupal and Brewer (2001) found significant improvements in knee strength, rehab anxiety and pain following a relaxation and guided imagery intervention with patients recovering from anterior cruciate ligament (ACL) reconstruction surgery. The imagery content included the physiological processes at work during each stage of recovery (e.g. visualise scar tissue releasing during wall slide), positive emotional coping responses (e.g. reinterpreting pain as pressure) and different sensory modalities (e.g. visual and kinaesthetic).

Personal meaning

It is now well acknowledged that a particular image can serve one or multiple functions depending on the meaning the image holds for the athlete (e.g. Callow and Hardy, 2001; Hall *et al.*, 1998; Nordin and Cumming, in press b; Short *et al.*, 2002, 2004a, 2006; Vadocz *et al.*, 1997). Indeed, Martin *et al.* (1999) borrowed the concept of meaning from Ahsen's (1984) triple-code model to explain that the same image can be interpreted differently across athletes and elicit different individual reactions. As we will see later in the chapter, the concept of personal meaning also plays a similar role in Lang's bioinformational theory (1979) as one of three types of propositional information (i.e. meaning propositions). Martin *et al.* illustrated the point with the findings of Hale and Whitehouse (1998) who asked football players to imagine taking a potentially game-winning penalty kick with either a "pressure" or "challenge" appraisal emphasis. Those participants in the challenge situation reported their anxiety symptoms to be more facilitative than participants in the pressure situation. Responses made by participants in interviews or open-ended questionnaires at the completion of intervention studies also reinforce the idea that the imagery experience is a highly personal one. For example, a golfer participating in an MGM imagery study (Nicholls *et al.*, 2005) described his images as serving an MGA function (e.g. ease worries, decrease tension) in addition to the intended MGM (e.g. feel more confident and focused). For similar reasons, Short *et al.* (2004a) suggested that researchers should verify with their participants that the perceived image function is consistent with the research or intervention goals. Furthermore, when designing interventions, the imagery function should first be considered (Short and Short, 2005). Imagery content could then be decided upon in conjunction with the athlete to ensure that the images are serving the desired function. Moreover, Short and Short advised that the images selected are viewed as facilitative in manner. For instance, an elite rugby union player described certain MGA and MGM as debilitative and intrusive to his performance by creating inappropriate activation levels (Evans *et al*., 2004). He instead preferred to use technical and tactical images to achieve motivational outcomes, including increased motivation and self-confidence.

Sport situation

Of all the components included in the applied model, the least researched is the sport situation. Martin *et al*. (1999) reviewed preliminary evidence demonstrating that the use of imagery as a pre-competition strategy led to greater performance compared to a control group. They also pointed out that these studies did not include a manipulation check so it is unknown how much or what types of imagery were used by the participants. In the experiment subsequently carried out by Cumming *et al*. (2007), types of pre-competition imagery were compared, but actual performance was not assessed in case certain types had a debilitative effect on the performer. They found that images resulting in appropriate activation levels and psychological states for the athlete (MGA psyching up imagery, MGM imagery and coping imagery) led to greater predictions of performance compared to those that did not (MGA anxiety imagery, MGA relaxing imagery). The next step would be to carry out intervention research that is particular to pre-competition as well as the other timeframes outlined in the applied model (i.e. training and rehabilitation). Further contexts have also been suggested, including exercise situations (Hall, 2001) and phases of the competitive season (Cumming and Hall, 2002a), which can also be considered when planning an intervention study.

Imagery ability

According to the applied model, the effectiveness of an imagery intervention will be dependent on the athletes' ability to image. Research supports this assertion by demonstrating that individuals higher in imagery ability show greater performance improvements following a skill-based imagery intervention (e.g. Goss *et al*., 1986; Rodgers *et al*., 1991). McKenzie and Howe (1997) found that imaging ten dart throws across 15 treatment days led to enhanced self-efficacy only for participants with superior imagery ability. Furthermore, Vergeer and Roberts (2006) found that flexibility gains were positively associated with reports of imagery vividness. As a more complete test of the model, Gregg *et al*. (2005) examined whether ease of imaging influenced the relationship between different types of imagery and track-and-field performance over an indoor season. Visual and kinaesthetic imagery ability significantly predicted greater CS imagery use, but the interaction between CS imagery and imagery ability failed to predict an athlete's best performance of the season.

Evidence in support of imagery ability as a moderating variable has recently been found in a study with exercisers (Cumming, in press). Concerns have been raised by Gregg *et al*. (2005) and others (e.g. Martin *et al*., 1999) that typically employed imagery ability questionnaires, such as the revised version of the Movement Imagery Questionnaire (MIQ-R; Hall and Martin, 1997), are not designed to assess the motivational aspects of imagery. Cumming therefore added companion scales assessing ease of imaging to the Exercise Imagery Inventory (EII; Giacobbi *et al.*, 2005). Similar to the SIQ and DIQ, the EII normally assesses the frequency with which individuals use different imagery types (i.e. appearance-health imagery, exercise technique imagery, exercise self-efficacy imagery and exercise feelings imagery). Of these types, it was found that exercisers' abilities to create appearance-health images moderated the relationship between imagery frequency and leisure-time exercise, coping efficacy and scheduling efficacy. This interaction revealed that exercisers who imaged their appearance and health more frequently and found it easier to see and feel these images, also tended to exercise more. Moreover, these individuals also had stronger beliefs about their ability to cope with challenges and difficulties related to exercising, and scheduling exercise sessions. Consequently, there is now some existing evidence to suggest that imagery ability is a moderating variable for imagery types beyond that of skill-based ones and outcomes in addition to performance. Although more testing is needed, particularly with valid and reliable measures of imagery ability, the findings do reinforce recommendations made to include strategies for improving imagery ability when planning imagery interventions.

Summary

The introduction of the applied model to the sport imagery literature has sparked an abundance of studies, both cross-sectional and experimental in nature, to test the various predictions made. In addition to building a literature surrounding the model, other positive consequences can be noted in terms of the methodological concerns previously outlined. Not only are the studies guided by a theoretically and empirically based model, but have also tended to include measures to screen for possible confounding variables and manipulation checks to verify that the intervention is being received and carried out as intended. The model has therefore achieved its main aim of being a useful guide for both research and applied work. Our review of this literature has led us to suggest that the predictions made by the model are also generally supported. However, there is a need to clearly distinguish imagery type from function, with image-meaning bridging the gap between concepts. Researchers should therefore consider different ways of establishing the perceived imagery function and to monitor whether these perceptions change throughout the intervention. This recommendation is particularly important to consider when there is not an obvious congruence between what the athlete is imaging and why. There is also enough evidence to now include additional imagery types and outcomes in the model. Others (Murphy *et al.*, in press) have further commented on individual difference variables (e.g. age, gender, participation level, motivational orientations, etc.) and other moderators (e.g. duration and amount, deliberateness, direction, perspective) that may also be considered. Finally, the applied model has been generally examined in injury rehabilitation, exercise, sport and dance. However, there has been limited work done so far in specific situations (e.g. during training, prior to competition) and more research is encouraged in this respect.

The PETTLEP model of motor imagery

The PETTLEP model of motor imagery (Holmes and Collins, 2001, 2002) is founded on the notion that a functional equivalence exists between imagery and motor performance. That is, similar brain structures to those that coordinate overt actions (i.e. motor structures) are also activated during imagery of actions (e.g. Ehrsson *et al.*, 2003; Fadiga *et al.*, 1999). Moreover, it is this similarity in neural activity when one performs imagery practice that provides the mechanism through which imagery functions to modulate subsequent motor and sports performance. Importantly, it has been argued that the effectiveness of an imagery intervention is determined by how well these same brain areas are activated through imagery (Holmes and Collins, 2002). In light of this proposed mechanism, the PETTLEP model of motor imagery was designed as a tool that sport scientists could use to heighten the equivalence between imagery and actual performance and thus improve the effectiveness of imagery interventions.

The acronym "PETTLEP" represents the seven elements of the model: **P**hysical, **E**nvironment, **T**ask, **T**iming, **L**earning, **E**motion and **P**erspective. The fundamental premise behind each element is the same: in order to maximise functional equivalence and therefore optimise the impact of an imagery intervention, the imagery performed should match actual performance as closely as possible. The "physical" element is concerned with the extent to which the physical nature of imagery reflects that of actual performance. For example, a batsman in cricket who is mentally practising a shot should assume a characteristic posture, wear typical sportswear, hold appropriate equipment and image the physical responses that would occur in real performance of the skill. The "environment" element refers to the physical environment that the magery is performed in being identical (if possible) to the actual performance environment. Moreover, the imagery environment should mimic a personalised and multisensory experience akin to the real-life performance of any given individual. In continuing with the above example, imagery of a cricket shot should ideally be performed on an individual's actual cricket pitch – or, if this is not possible, photographs or DVDs could be used as an alternative. The "task" element suggests that the imaged task should correspond as closely as possible to the real task. That is, the specific content of imagery performed should specifically mimic actual performance. For example, a cricket player should mentally practise the type of shots they would typically play in a match, thus reflecting their current level of performance or stage of learning. The "timing" element conveys that imagined performance should be temporally matched to the same speed as actual performance (i.e. real-time). The "learning" element suggests that an individual's imagery practice should be analogous to their current stage of learning and subsequently acclimatise as skill level develops. The "emotion" element suggests that imagery should incorporate all emotions and arousal typically experienced during actual performance. However, it has been since noted that any negative thoughts that could be detrimental should be replaced with positive ones (Smith *et al.*, 2007). The "perspective" feature suggests that imagery should be performed from a visual perspective that represents the view taken by the athlete when actually performing the task (i.e. internal or external). While there has been debate in the literature on the benefits of one perspective over another (e.g. Cumming and Ste-Marie, 2001; Hardy and Callow, 1999), within the PETTLEP model both perspectives are considered to access appropriate motor representations and potentially strengthen the neural network. Moreover, sports performers may find that the perspective taken during imagery practice may be contingent on the demand of the task being imaged. It has previously been demonstrated that taking an external perspective can be more beneficial when form or body coordination is an important feature of the to-be-learned movement. Conversely, it is more advantageous to use an internal perspective for open skills that depend heavily on perception for their successful execution (Hardy and Callow, 1999). Therefore, Holmes and Collins (2001) suggested that the imagery perspective employed should be appropriate for both the individual and the task.

In accordance with bioinformational theory (Lang, 1977, 1979, 1985), the PETTLEP model also advocates that, for imagery to be optimally effective, each element should include stimulus (i.e. information concerning the stimuli in the environment), response (i.e. the cognitive, behavioural and affective responses of an individual to given stimulus in an environment) and meaning propositions (i.e. the perceived importance of the behaviour). By including these propositions into imagery practice, the correspondence (or functional equivalence) to physical practice should increase which, in turn, should raise the effectiveness of an imagery intervention at facilitating performance.

Evidence

Following the publication of the PETTLEP model, there has been a growing endeavour to empirically test the assumptions made. To this end, experimental studies have proved valuable for affirming the viability of the model as an effective tool to raise the functional equivalence that imagery has with performance and, in doing so, increase the effectiveness of imagery interventions delivered in sporting settings. More specifically, consistent evidence has been provided which highlights that imagery more functionally equivalent to actual performance will have more pronounced effects on subsequent sports performance compared to less functionally equivalent imagery (Callow *et al.*, 2006; Smith and Collins, 2004; Smith and Holmes, 2004; Smith *et al.*, 2001, 2007).

Clear and consistent evidence has demonstrated that manipulating the "physical" and "environment" elements of the model has beneficial effects on sports performance (Smith and Collins, 2004; Smith *et al.*, 2001, 2007). For example, one experiment from Smith *et al.* (2007) involved implementing a six-week imagery intervention with university-level hockey players where the physical and environment components of the PETTLEP model were manipulated. Three different intervention groups used imagery to practise ten hockey penalty flicks every day for six weeks. Each group either: (a) wore hockey clothes while standing on a hockey pitch (i.e. physical + environment), (b) wore hockey clothes while standing at home (i.e. physical only) or (c) wore normal clothes while sitting down at home (i.e. no PETTLEP elements). The control group did not perform imagery but instead read hockey literature. The post-test results showed that the most functionally equivalent form of imagery practice (i.e. wearing hockey clothes while standing on a hockey pitch) scored significantly higher compared to a less functionally equivalent forms of imagery practice (i.e. wearing hockey clothes while standing at home or wearing normal clothes at home). All forms of imagery practice resulted in significantly higher performance scores compared to control. These data support the assumption that to maximise performance facilitation from imagery interventions, the physical and environment aspects of the model should be delivered in a functionally equivalent manner.

Ramsey *et al.* (2007) manipulated the "emotion" element of the model using a sample of university football players. In their study, participants took ten penalties prior to and following a six week intervention period. Two imagery interventions, which differed only in their emotional content, were compared to a control group who performed a stretching routine. Each group performed their intervention four times per week with approximately half the sessions performed on their football pitch and the other half at home. At post-test, both imagery groups scored significantly higher points than the control group, but no significant differences were observed between the two imagery groups. These particular findings again support the contention that using PETTLEP-based imagery practices is an effective way to design performance-facilitating imagery interventions in sport. However, the data do not support the model's proposal that increasing functional equivalence through the inclusion of emotions felt during real-life performance has any beneficial effect on sports performance. However, it should be noted that the authors recognised that the testing environment for the experiment was not a competitive live-match atmosphere. Consequently, the inclusion of competitive emotions in one of the imagery interventions may not have resulted in additional benefits to performance due to the lack of actual competitive emotions felt during the post-test session. A tentative proposal is offered by Ramsey *et al.* that elements of the model may function differently in training and competition. However, this needs to be empirically tested and is an interesting area for future research.

The studies outlined above measured the effect on sports performance of individual elements of the PETTLEP model or, in some cases, combinations of different elements. Investigating all seven elements together, Smith *et al.* (2007; Experiment 2) compared two imagery groups to a physical practice group and a no-imagery control on the performance of a Full Turning Straight jump on a gymnastics beam. The imagery groups either performed: (a) imagery consisting of all seven elements of the model, or (b) imagery using a written script that included descriptive information about the environment and task (i.e. stimulus propositions). Each group performed their task three times per week for six weeks. The results demonstrated that the physical practice group and the PETTLEP imagery group performed better than the other two groups in the post-test. Additionally, no differences were found between the physical practice group and PETTLEP imagery group.

Summary

Altogether, there is growing evidence confirming the predictions made by the PETTLEP model. The central focus of these findings has suggested that the PETTLEP model of motor imagery is an effective tool for designing performance-facilitating imagery interventions in sport. Furthermore, the majority of evidence is consistent with the model's proposal that more functionally equivalent imagery interventions provide more compelling performance-facilitation effects compared to imagery interventions less functionally equivalent with performance. A main strength of the model is that it is underpinned by robust neuroscientific evidence and a clearly articulated mechanism for the observed performance effects from imagery practices. However, the model is still relatively new and has not yet been widely tested. We encourage researchers to continue testing each element of the model, in isolation and in combination with other elements. In this way, individual element characteristics could be discerned as well as the interactive effects with other elements of the model. Such findings may reveal that certain elements are more important to manipulate than others to achieve the specific desired outcome (e.g. improved performance, increased self-efficacy and modified interpretations of anxiety).

A further important future development for the PETTLEP model would be for testing to take place in a variety of settings with a mixture of populations. Not only is the model relevant for a variety of sporting environments with athletes of differing levels of ability, but also clinical and rehabilitative populations. The latter setting may include patients who have lost function in limbs and need recovery or clinicians who aim to develop motor expertise. In addition to these future developments, some limitations of the model should be recognised. Even though evidence has been presented showing performance benefits following the inclusion of all seven PETTLEP elements (Smith *et al.*, 2007; Experiment 2), it may not always be feasible to do so. For instance, sick or injured athletes who use imagery as a substitute for training sessions they cannot complete may find it difficult to satisfy the "physical" and "environment" elements of the model. As a compromise, these athletes could hold relevant sporting equipment during their imagery practices and incorporate kinaesthetic feelings but be unable to adopt the physical position. In addition, athletes may use imagery to supplement training when they cannot make it to the sports facilities. In this instance, when the "environment" cannot be manipulated, the athletes might make use of pictures/

video clips of the venue as well as to focus more so on the other PETTLEP elements to optimise functional equivalence.

Implications for professional practice

Our review of the literature has revealed that researchers are taking heed of previous recommendations to improve the methodology of imagery studies and adopt testable frameworks to guide their work. While this is now becoming the norm for studies published over the past five years or so, there are still exceptions slipping through the net. Rather than highlight the weak studies, we will instead emphasise elements of good practice evident in the literature with the hopes that these become standard among imagery researchers. Goginsky and Collins (1996) have also made a detailed list of recommendations for the interested reader to consider when planning their own research design.

Screening measures

Measures are often given prior to the commencement of an imagery intervention to provide researchers with information about their participants' previous experience with and knowledge of imagery as an intervention technique. Athletes' perceptions of imagery are important to consider because they are less likely to image when they do not perceive it as being relevant to improving their performance or competing effectively (Cumming and Hall, 2002a). Information can therefore be given to participants about the nature of imagery and the typical benefits received. Moreover, athletes with low imagery abilities are also less likely to benefit from an intervention. Assessing their general ability to image may reveal that training exercises are necessary before the intervention is given. The majority of researchers have shown a preference for using the MIQ-R, and applied the criteria of scoring at least a 16 (i.e. images are neither easy or difficult; Callow *et al.*, 2001, 2006; Smith and Collins, 2004) on both the visual and kinaesthetic sub-scales to indicate adequate imagery ability. Others have used more stringent criteria of scoring at least 20 (i.e. images are somewhat easy to see or feel; Short and Short, 2005; Short *et al.*, 2002). An alternative measure is the Vividness of Movement Imagery Questionnaire (VMIQ; Isaac *et al.*, 1986), with researchers using the criteria of scoring under 72 (Hardy and Callow, 1999; Smith and Holmes, 2004). Researchers have also administered the SIQ to examine athletes' frequency of imaging (Cumming *et al.*, 2004; Evans *et al.*, 2004). However, it is important to point out that the original version of this questionnaire does not assess ability unless certain dimensions are added (e.g. ease of imaging, vividness, controllability; see Cumming, in press; Nordin and Cumming, in press b).

As far as we know, research has yet to establish whether a particular score on the MIQ-R and VMIQ does indeed indicate that a participant will benefit from the intervention, and would suggest this to be valuable line of enquiry for future research. Moreover, we would like to encourage researchers to carefully consider whether the information gained from these measures will be appropriate for the nature of the intervention given. Goginsky and Collins (1996) raised a similar point by asking researchers to consider whether the imagery questionnaires are appropriate to the task. If the intended intervention will focus on motivational images, for example, it might be more enlightening to use the Motivational Imagery Ability Measure for Sport (MIAMS; Gregg and Hall, 2006) or the SIQ with added imagery ability dimensions. They also suggested that the task being imaged might demand a particular type of imagery ability that cannot be appropriately measured with currently established questionnaires. Researchers have consequently developed study-specific measures to use alongside questionnaires that have previously been validated (e.g. Cumming and Ste-Marie, 2001). Finally, these screening measures can also be re-administered at the end of the intervention to examine changes in the imagery process. No study has yet examined, for example, whether an athlete's ability to create motivational or emotional images improves with experience.

Manipulation checks

Because imagery is not an observable behaviour, it is important to have documented evidence that participants are engaging in the intervention (Goginsky and Collins, 1996). Manipulation checks are now more commonly employed during and at the completion of an intervention to verify that the imagery is being used as intended. In certain interventions, athletes have also been encouraged to modify the imagery content to suit their individual needs and note the changes made (e.g. Munroe-Chandler *et al.*, 2005). These manipulation checks are normally designed specifically for the needs of a particular study, but some researchers have also administered validated questionnaires such as the full SIQ (Callow *et al.*, 2001; Evans *et al.*, 2004) or a shortened version (Munroe-Chandler *et al.*, 2005). Field-based interventions will often ask participants to report on their imagery perspective, ease of imaging, use of imagery as outlined in script, number of imagery sessions completed, and perceived effectiveness of the imagery (Callow and Waters, 2005; Callow *et al.*, 2006; Cumming and Ste-Marie, 2001; Munroe-Chandler *et al.*, 2004, 2005; Ramsey *et al.*, 2007). Imagery diaries monitor participants' use of imagery throughout an intervention (Callow and Waters, 2005; Cumming *et al.*, 2004; Ramsey *et al.*, 2007; Shambrook and Bull, 1996; Smith *et al.*, 2001). Participants may be asked to note difficulties that they encounter during imagery or use the diary as a self-monitoring strategy to promote adherence to the intervention. Social validation checks are also employed to verify whether procedures were acceptable to the participant and if they were satisfied with the results (Hanton and Jones, 1999; Jordet, 2005). Similarly, post-intervention interviews are used to gain a more in-depth account of the participants' view of the intervention (Callow *et al.*, 2001; Jordet, 2005; Smith *et al.*, 2001). Finally, experimentally designed research will employ manipulation checks to establish understanding of and adherence to instructions given, the use of other psychological strategies and demand characteristics (e.g. whether participants guessed the true nature of the experiment and acted in accordance with this purpose; Feltz and Riessinger, 1990; Goginsky and Collins, 1996; Martin and Hall, 1995; Nordin and Cumming, 2005a; Ramsey *et al.*, in press; Taylor and Shaw, 2002).

Training exercises

Researchers have employed training exercises prior to the commencement of an intervention to develop the imagery abilities of participants (e.g. Callow *et al.*, 2001; McKenzie and Howe, 1997), to clarify the difference between internal and external imagery perspectives (e.g. Blair *et al.*, 1993), or to introduce the participants more generally to the concept of imagery (e.g. Callow and Waters, 2005). Callow and Waters (2005) have used Hardy and Fazey's (1990) Mental Rehearsal Programme to first introduce participants to general imagery training, which was then followed by standardised training in the targeted imagery type (i.e. kinaesthetic imagery). Others have followed recommendations made by Lang *et al.* (1980) to carry out exercises that make participants more aware of the stimulus and response information in their imagery (Cumming *et al.*, 2007; Smith and Collins, 2004; Smith and Holmes, 2004). This procedure is based in bioinformational theory and involves drawing the participants' attention towards specific stimulus details of the scene as well as encouraging them to experience relevant physiological and emotional responses during their imagery. A similar method to improving imagery ability is to introduce images in layers, starting with simple images and then adding details or different sensory modalities in sequence. For example, Calmels *et al.* (2004a) carried out an imagery intervention to improve the selective attention of three national softball players while at bat. The intervention involved 28 imagery sessions organised in five stages describing the successful performance of different batting scenarios (e.g. balls delivered as curve balls or fast balls). With each stage, the amount of detail and complexity of the scenario being imaged increased by including the position of potential runners on different bases and possible distracters (e.g. weather, noise, unfair umpire). The participants demonstrated improvements in at least two of the three dimensions of selective attention measured (i.e. effectively integrate many external stimuli at one time, narrow attention when needed, and make fewer mistakes due to being overloaded by external stimuli). In another paper, Calmels *et al.* (2004b) also described significant improvements in vividness ratings (ranging from 15.8 per cent to 32.3 per cent) for these players.

Rather than excluding individuals from studies due to their low imagery ability, imagery exercises may instead provide an opportunity to develop these abilities to a level where the intervention would be successful. Not only would participation be maximised, but employing these exercises would also reinforce to athletes that imagery is a skill that can be developed and refined through practice. We consequently encourage researchers to incorporate training exercises when appropriate into their intervention, using theory as a guide. Moreover, the nature of these exercises should be reported in papers to make replication possible in future work. The extent to which exercises enable participants to create more vivid images has not yet been extensively evaluated. Nor, as mentioned above, have criteria been established for the necessary level of imagery ability to be achieved before imagery interventions become successful. Both issues would be useful lines of future research enquiry for the continued improvement of imagery interventions.

Individualising the intervention

The possible benefits of individualising the imagery intervention include the athletes finding the intervention more meaningful, enjoyable and easier to perform, increased adherence, and continued use of imagery following termination of the study. Single-subject multiple-baseline designs are a feasible means to individualising the intervention because: (a) large samples are not necessary; and (b) design complexity can be reduced (Callow and Hardy, 2005; Callow *et al.*, 2001). In this design, the intervention is introduced to the different participants at staggered points of time. If the baselines of all participants change when the intervention is introduced, then the effects can be attributed to the intervention. In their study with three professional flat-race horse jockeys, for example, Callow and Waters (2005) developed five different imagery scripts in conjunction with each participant.

Action research was recently introduced to the imagery literature by Evans *et al.* (2004), and is another means to individualising an intervention with a small number of participants. They describe the aim of action research as being to solve day-to-day problems and/or intervene in real-life situations to improve practice (also see Castle, 1994). It involves a cyclical process of planning, acting, observing and reflecting with collaboration and feedback occurring between the researcher and client. The intervention is not predetermined in advance, but evolves in response to individual needs. Evans *et al.* highlighted several advantages of using this design to improve the imagery effectiveness of an elite rugby union player. They were able to gain detailed insights into the participant's use of imagery, particularly certain debilitative aspects of motivational images and a preference for using cognitive images. Moreover, they were able to conduct the intervention over 14 weeks of the competitive season, lending high ecological validity to the study. Finally, feedback was derived from multiple sources including semi-structured interviews, daily diaries and the SIQ.

It is also possible to individualise group-based research designs. In experiments examining the effect of response propositions on certain outcomes, for example, participants can be asked to provide stimulus information based on their own experiences (e.g. Cumming *et al.*, 2007). An alternative approach is to apply multiple baseline designs to the group level (e.g. Munroe-Chandler and Hall, 2004; Munroe-Chandler *et al.*, 2005).

In addition to personalising the content of an imagery script, researchers may also consider the participants' preferred mode of delivery. For instance, Callow and Waters (2005) gave participants the choice of what format they would like their imagery scripts to be presented in – as either collated in a written booklet or recorded on audiotape. In our work, we have found that athletes also voice a preference for who reads out the scripts, the perspective the script is written from (i.e. first person vs third person), and the tempo, pitch and rhythm of how the script is read. When video clips are supporting the imagery intervention, it also likely that participants may favour viewing the clips from a certain perspective (e.g. sideways, front on) or for the clips to depict a particular person (e.g. themselves, more accomplished athlete). Finally, it is also worth considering whether a script is even necessary. It might be the athlete's preference, for example, to receive general instructions and advice on the types of response propositions to base their imagery upon, rather than having a structured script to follow. For these reasons, we involve the athlete not only in the development of the imagery content but also in the finer details of how that imagery is delivered.

Objective measures of the imagery experience

Because imagery is an internal experience that cannot be directly measured, researchers tend to rely on the subjective reports of their participants. Although questionnaires and in-depth interviews are certainly informative and do have an important place in the research area, they are also limited to images experienced at a conscious level and are subject to some degree of retrospective bias. Objective measures can add further insights into the imagery experience while it is occurring and provide useful feedback to the participants. For instance, Olympic medallist Alex Bauman described timing his imagery of swimming races:

> The best way I have learned to prepare mentally for competitions is to visualize the race in my mind and to put down a split time. The splits I use in my imagery are determined by my coach and myself, for each part of the race. For example, in the 200 individual medley, splits are made up for each 50 metres because after 50 metres the stroke changes. These splits are based on training times and what we feel I'm capable of doing. In my imagery I concentrate on attaining the splits I have set out to do.
>
> (As quoted in Orlick, 2000: 116)

Within the research context, objective measures will indicate that images are actually occurring and provide evidence in support of certain theoretical frameworks. Heart rate, respiration rate and skin conductance are often obtained to demonstrate a basic tenet of bioinformational theory that vivid images containing response propositions will result in an actual physiological response (Cumming *et al.*, 2007; Gallego *et al.*, 1996; Hecker and Kaczor, 1988). Electromyographic (EMG) and electroencephalographic (EEG) recordings have similarly been used to test this hypothesis (Smith and Collins, 2004; Smith *et al.*, 2003).

As the PETTLEP model and the theory of functional equivalence grow in popularity, imagery researchers would also benefit from using techniques that are more common to the neurosciences. Indeed, advances in cognitive neuroscience may aid sport-imagery research to progress from a descriptive stage, where underlying mechanisms are speculated upon, to an explanatory stage, where underlying mechanisms can be more clearly discerned. One technique used to measure brain activity is functional magnetic resonance imaging (fMRI). Within the context of fMRI, a typical measure is the Blood Oxygen Level Dependent, or BOLD, response. The BOLD response is based on a physiological response to brain activation where red blood cells move from a state of oxygenation to deoxygenation during functional activity. At differing levels of oxygenation, the MR signal of blood is different and this difference can be detected by an MR pulse sequence. Thus, fMRI is not a direct or invasive measure of neuronal activity within the brain, but instead infers brain activity based on levels of blood oxygenation. An advantage of this technique is that it will indicate the degree of functional equivalence between imagery and actual movement by demonstrating common areas of brain activation. Unfortunately, due to the confined space with a scanner and the importance of maintaining a still head position, only a limited amount of movement can be performed during testing. As a result, the majority of fMRI studies investigating imagery to date have answered fundamental questions in terms of imagery and execution equivalence. For example, Ehrsson *et al*. (2003) used fMRI to measure brain activity during finger, toe and tongue actions. When compared to rest, the same premotor areas were activated during imagined and executed movements. Furthermore, the imagery activity was organised in a samatotopic fashion consistent with the motor homunculus. That is, brain activation during imagined finger, toe and tongue actions corresponded with the location of activation during actual finger, toe and tongue actions respectively. Hence, not only were similar motor structures active during imagery, but the activity was also organised in a similar manner.

The future for imagery research

Our review of the literature suggests a growing evidence base in support of both the applied model of imagery use and the PETTLEP model. Intertwined in our review are suggested avenues of future research with respect to predictions made by both models, and possible elaborations to the applied model. Investigating the interaction of both models is an obvious next step. The applied model enables investigators to consider the “why”, “what”, “where” and “when” of the intervention, whereas the PETTLEP model can specify the “how”. Take, for example, an intervention to be carried out with novice tennis players to improve service reception (CS imagery function) during training (sport situation). The physical and environment elements of PETTLEP can be included by having participants dressed in their kit, standing on the court and holding their racket. Furthermore, skill-based images (imagery type) that are performed in real-time (timing element) and match the individuals' current level of performance (task element) can evolve as further learning (learning element) takes place. Combining both models in a single intervention should enable functionally equivalent imagery to be performed that is personally meaningful to the individual in achieving their goals.

Another logical next step for imagery research is to move beyond healthy populations into clinical ones. Testament to this idea, a recent study has offered encouraging findings using imagery training as a restorative tool to assist patients with chronic spinal cord injury (Cramer *et al.*, 2007). They found that in participants devoid of voluntary motor control and peripheral feedback, imagery training improved motor performance and altered brain function. With this in mind, the applied model has already been proposed for use in rehabilitation and exercise settings (Hall, 2001). Also, as mentioned above, it would be useful to examine the PETTLEP with a mixture of populations. Consequently, sport scientists armed with theoretically based models would likely have a great deal to offer intervention work that is already becoming popular with clinical populations.

Finally, we have suggested that neuroscientific techniques, such as fMRI, can help to explain why imagery interventions function to improve sporting performance. A further important use of fMRI in imagery research is to take steps towards validating imagery questionnaires. Pen and paper imagery assessments are commonly used – results from which make valuable contributions to our understanding of imagery–behaviour relations. However, if a more objective measure, such as brain activity, correlated with questionnaire forms of imagery indices then this would affirm the viability of questionnaire-based imagery assessments that are typically used in the field. For example, Amedi *et al.* (2005; see also Cui *et al.*, 2007) found a positive correlation between the BOLD response activity during visual imagery of objects with scores on the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973). This study highlights the potential capability for brain activity to function as a more objective measure of one's imagery abilities in comparison to questionnaire-based assessments.

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