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CHAPTER

11 The Role of Imagery in Performance

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Abstract

Imagery is both a fundamental cognitive process for producing motor actions and a performance-enhancing technique widely used by athletes and dancers. In this chapter, we review findings from basic and applied research to comprehensively define imagery and describe its key characteristics. Using a cognitive neuroscience explanation, we discuss how imagery is involved with motor skill performance and the practical implications for this explanation in planning more effective interventions through application of the PETTLEP model (Holmes & Collins, 2001). We also focus on the development of imagery ability, an important individual difference variable impacting the value of imagery, and discuss how certain aspects of this characteristic can be improved. We then describe other imagery outcomes and offer a revised model based on our review to guide further research and application. We conclude with future directions for imagery research and its practical use for performers, including contemporary issues to be addressed by researchers in the field.

Key Words: Functional equivalence, modality, perspective, agency, angle, deliberation, learning, performance, application, PETTLEP, applied model of imagery use

Imagery is a cognitive process fundamental to motor learning and performance. When we consciously internally represent an action through imagery, the same brain areas involved in the unconscious planning and execution of movements are activated (Lotze & Halsband, 2006; Munzert, Lorey, & Zentgraf, 2009). Importantly, imagery shares neural and behavioral similarity to the genuine experience. This functional relationship provides researchers with a direct approach to studying covert motor processes important in everyday life, such as anticipating the effects of an action, preparing or intending to move, learning or relearning motor skills (e.g., recovery after stoke), or remembering an action (Jeannerod, 1995). Due to this wide application and ability to gain insights into underlying mechanisms, imagery is of interest to a range of fields including cognitive psychology, neuropsychology, neurophysiology, neurorehabilitation, motor learning, motor control, and physiotherapy (Lotze & Halsband, 2006; Munzert et al., 2009; Murphy & Martin, 2002).

Imagery is also a mental technique that can be refined with practice and utilized in many ways. It is a well-known performance-enhancing strategy and extensively used in applied fields, particularly sport, dance, and exercise psychology (for a review, see Cumming & Ramsey, 2009; Murphy, Nordin, & Cumming, 2008; Weinberg, 2008). A main function of imagery is to aid self-regulation of thoughts, feelings, and behaviors, and it is a characteristic of successful performers (e.g., Cumming & Hall, 2002; Orlick & Partington, 1988; Salmon, Hall, & Haslam, 1994). Many anecdotal reports exist from elite athletes and dancers describing the significant role played by imagery in their preparation for top

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performances. For example, sprinter John Regis described training for a major championship by, "imaging the perfect race and the feeling I got when I was running the perfect race. When that happens it's called being in the zone, because you just don't seem able to lose or run badly" (Grout & Perrin, 2004, p. 103).

In this chapter, we pull from varied research areas to offer different perspectives on imagery and more fully describe this dynamic, complex, and ubiquitous construct. We begin by providing a definition to explain five key characteristics of the imagery process. Using a cognitive neuroscience explanation, we discuss how imagery is involved with motor skill performance and the practical implications for creating more effective imagery. Our discussion then broadens to include other imagery outcomes, and we offer a revised model to guide further research and application. We conclude with several contemporary issues to provide direction for future investigations in the field.

Defining Imagery and Its Characteristics

Defining the term "imagery" has not proved to be a simple or easy task. Many definitions offer different descriptions of what imagery entails and explanations about its many functions. Morris, Spittle, and Watt (2005) explain "the focus of each definition varies depending on the purpose for which the imagery description is used" (p. 14), which makes it difficult for authors to select a single conceptualization of the construct. A consistent theme is to consider imagery as a mental activity involving the internal representations of information without the stimulus present (Moran, 2009). Recently, Holmes and Calmels (2008) adapted Morris et al.'s working definition to account for neuroscientific evidence of the shared neural activation between imagery and physically executed behavior:

> Imagery, in the context of sport, may be considered as the neural generation or regeneration of parts of a brain representation/neural network involving primarily top-down sensorial, perceptual and affective characteristics, that are primarily under the conscious control of the imager and which may occur in the absence of perceptual afference functionally equivalent to the actual sporting experience. (*Holmes & Calmels*, 2008, p. 433)

We will use this definition as the starting point for describing five key characteristics of the imagery process: modality, perspective, angle, agency, and deliberation (see Table 11.1 for a summary). Although a sport setting is specified, this definition applies to the range of performance circumstances discussed in this chapter.

Table 11.1 Key characteristics of the imagery process

Characteristic	Definition	Components
Modality	The sensory modality (or modalities) involved.	Auditory Gustatory Kinesthetic Olfactory Tactile Visual
Perspective	The visual perspective adopted.	1PP (internal visual imagery) 3PP (external visual imagery)
Angle	The viewing angle when imaging in 3PP.	Above Front Behind Side on (from right or left)*
Agency	The author or agent of the behavior being imaged.	Self Other
Deliberation	The degree to which imagery is consciously and purposefully employed.	Spontaneous or triggered Deliberate mental practice

For a more extensive list of viewing angles, see Callow, N. & Roberts, R. (2010). Imagery research: An investigation of three issues. *Psychology of Sport and Exercise, 11,* 325–329.

At its most basic level, Holmes and Calmels describe imagery as a top-down, knowledge-driven process. The starting point for image generation is typically, but not necessarily, when individuals close their eyes (Holmes & Camels, 2008). Information is then retrieved from long-term memory to use within working memory to create or recreate an experience (e.g., Morris et al., 2005). It is here where other imagery subprocesses occur, namely image transformation (i.e., rotate or modify the characteristics of an image), image scanning (e.g., detect details in the image), and image maintenance (e.g., sustain images for a period of time). Imagery is therefore dynamic in nature, involving other cognitive processes such as memory. It is also not limited to recalling information from the past, but also allows individuals to create new experiences that have not yet occurred (Denis, 1985).

Another element of Holmes and Calmels' (2008) definition is the idea that imagery is a quasi-sensory or perception-like process happening in the absence of any external stimulus input (also see Kosslyn, Thompson, & Ganis, 2006; Richardson, 1969). The imagined perceptual experience can occur in different sensory modalities; namely, auditory, gustatory, kinesthetic, olfactory, tactile, and visual. Visual imagery is experienced as seeing with the "mind's eye," auditory imagery is experienced as hearing with the "mind's ear," tactile imagery is experienced as feeling with the "mind's skin," and so on (Kosslyn et al., 2006). Further, defining imagery as a multisensory construct is also consistent with how athletes, dancers, and exercisers describe their imagery experiences (Driediger, Hall, & Callow, 2006; Munroe, Giacobbi, Hall, & Weinberg, 2000; Nordin & Cumming, 2005b; Short, Hall, Engel, & Nigg, 2004).

When imagery pertains to simulating an action or movement, the focus is typically on visual and kinesthetic modalities. The visual representation contains information about what the individual "sees" in the image (e.g., your club head making contact with the ball when playing golf), and this can be viewed from either a first-person (1PP) or third-person perspective (3PP). In 1PP, also known as *internal visual imagery*, the movement is imaged as if the individual is taking part in the actual action; that is, through their own eyes. By comparison, the individual would occupy the position of an observer in the 3PP and image the action from outside of his or her own body; that is, as if watching themselves performing on television or on a stage. For this reason, 3PP is also known as *external visual imagery*.

Particularly in the case of the 3PP, single or multiple angles can be adopted to provide individuals with additional visual information about the movement to be performed (Holmes & Calmels, 2008). Professional dancers interviewed by Nordin and Cumming (2005b) described seeing themselves from above and/or diagonally, as well as experiencing both visual perspectives simultaneously. More recently, Callow and Roberts (2010) reported ten different viewing angles employed by participants when they completed the external visual imagery subscale of the Vividness of Movement Imagery Questionnaire-2 (VMIQ-2; Roberts, Callow, Hardy, Markland, & Bringer, 2008). The four most reported angles were behind, in front, side on from the left, and side on from the right. From this research and anecdotal reports (e.g., Holmes & Calmels, 2008), it is evident that performers transform or rotate images to take advantage of different viewing angles. They also alternate between viewing perspectives as it suits the nature of the task and/or their stage of learning.

Although hypotheses are less advanced for viewing angle, 1PP has been found to benefit simple, well-learned tasks and those depending on perceptual information (e.g., anticipating the direction of the ball when receiving a serve in tennis) whereas 3PP is more useful for tasks emphasizing technical form or body shape (e.g., the precise body movements involved in performing a spiral sequence in figure skating) (Hardy, 1997). It is plausible that specific or multiple angles may further enhance the effects of 3PP for form-based tasks by providing the imager with visual information not otherwise accessible to them in 1PP. For example, a ballet dancer may image herself from behind, the front, and the side to analyze her body position when performing an attitude or développé. Further, utilizing different viewing angles might aid in the learning and memorization of tactics and strategies. As another example, viewing the football pitch from above may help a player to understand where his needs to be positioned in relation to his teammates.

In addition to viewing perspective and angle, it is also important to clarify the behavioral agency or authorship of the visual image. Individuals can image their own performance or that of another person (Holmes & Calmels, 2008; Ruby & Decety, 2001). 1PP is typically associated with the self being the agent of one's behavior, but this can also refer to adopting the perspective of someone else. The latter allows the individual to put him- or herself in the place of another person (e.g., "put yourself in their shoes") to predict and understand the actions of others (Jeannerod, 2006). In 3PP, either the self or another person can be seen as the agent of the behavior. For example, a basketball player might mentally create a scene involving his or her team member successfully performing a foul shot and view it from the position he or she normally occupies on the court. Imagery research can sometimes be ambiguous as to whether 3PP is referring to the self or other performing the action, and this lack of distinction may potentially confound study results. At a neural level, behavioral agency can be distinguished with brain imaging techniques such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), or transcranial magnetic stimulation (TMS). Using PET, Ruby and Decety (2001) asked participants to image either themselves or the experimenter performing a given action, in this case, acting with a particular object (e.g., a razor, shovel, or ball). Although an overlap in neural networks was found, distinctive areas were activated during the internal representation of self-produced actions compared to when simulating the actions generated by others. Imaging oneself making the action mirrored the pattern found during actual execution of the movement, whereas imaging others generating the action was akin to activation occurring when individuals watch the movements of others.

The kinesthetic modality of movement imagery involves representing the sensations of how it "feels" to perform an action, such as the tension in your muscles when they contract as you run up a flight of stairs. This internal feel involves an awareness of the position and movements of the parts of the body, known as *proprioception* or *kinesthesia*, as well as the force and effort perceived during movement and effort (Callow & Waters, 2005). It may also consist of other types of feelings relevant to the performer or nature of the task. Qualitative research suggests that imaged feelings also include physiological responses (e.g., changes in heart rate or body temperature), pain and healing (e.g., imaging how a ligament tear feels and how it heals during the rehabilitation process), emotions (e.g., feeling happy), rhythm and timing (e.g., imaging in slow or fast motion), weight (e.g., feeling light or heavy), and spatial awareness (e.g., bodily position and/or position in relation to other objects) (Callow & Waters, 2005; Driediger et al., 2006; Nordin & Cumming, 2005b). Thus, many interpretations may result when performers are asked to rate how easy or difficult it is for them to feel an image, such as when asked to complete manipulation checks about their imagery experiences. For the sake of clarity in research, as well as applied settings, what is meant by "feel" should be specifically defined for, or by, participants.

A conceptual distinction between imagery modality and perspective is also needed because the term "internal imagery" has historically been equated with kinesthetic imagery. The confusion likely stems from Mahoney and Avener's (1977) seminal paper highlighting imagery as an internal characteristic of successful gymnasts at the 1976 U.S. Olympic trials. Although Mahoney and Avener defined internal imagery as "being inside his/her body and experiencing those sensations which might be expected in the real life situation" (p. 137), the gymnasts were asked whether they experienced what the image would feel like in their muscles (i.e., kinesthetic imagery). Subsequent research has not always found internal imagery to be favored by successful performers (Ungerleider & Golding, 1991). It is also now well established that individuals are capable of experiencing kinesthetic sensations when imaging from an external visual perspective (Cumming & Ste-Marie, 2001). For these reasons, imagery perspective is now more appropriately considered the viewpoint that an individual takes during imagery rather than the sensory modality involved (Hardy, 1997; Morris et al., 2005).

Importantly, individuals can detect a difference between visual and kinesthetic imagery, but these modalities do not occur in isolation. It is possible to experience more than one modality simultaneously and shift attention between modalities as instructed (Munzert et al., 2009). When completing the Movement Imagery Questionnaire-Revised (MIQ-R; Hall & Martin, 1997), participants are asked to rate their ease of "seeing" and "feeling" four movements (knee raise, arm movement, waist bend, and jump). Although scores for visual and kinesthetic imagery ability tend to be positively correlated with each other, the strength of this relationship is only moderate in nature ($r = .44$; Hall & Martin, 1997). From a psychometric point of view, visual and kinesthetic imagery of movement appear to be separate but related constructs.

Further, there is evidence that visual and kinesthetic imagery are neurally discernible (e.g., Guillot et al., 2009). Using fMRI, Guillot et al. revealed a divergent pattern of increased brain activation in skilled imagers following instructions to first-person visually or kinesthetically image a finger sequence consisting of eight moves. Both types of imagery shared common activations related to movement

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(i.e., lateral premotor cortex), but areas involved with visual perception (i.e., the occipital regions and the superior parietal lobules) yielded more activity during visual imagery, whereas kinesthetic imagery resulted in greater activity in structures associated with motor processes (i.e., the inferior parietal lobule). The authors concluded that individuals are able to selectively attend to one sensory modality when generating an image, but will still have a general mental representation of the movement regardless of whether the sensory modality is visual or kinesthetic. This finding also helps clarify the concept of motor imagery, which Moran (2009) argues has been too narrowly defined by cognitive neuroscientists. It is a commonly used term, but there is no definite agreement on how it should be defined. For example, Decety (1996) describes motor imagery as being comparable, "to the so-called internal imagery (or first person perspective) of sport psychologists" (p. 87). Jeannerod (1994) takes a more general approach by explaining motor imagery as the mental representation of an overt action without associated movement. The extant fMRI evidence makes it clear that motor images do consist of both visual and kinesthetic representations. Thus, motor imagery is probably most appropriately defined by describing content rather than the modality, perspective, or agency involved. However, to avoid confusion, these latter characteristics should be specified when providing instructions to research participants or performers in applied settings.

The final characteristic of imagery discussed here is that it differs from dreaming because individuals are awake and conscious when generating images (White & Hardy, 1998). How aware and purposeful individuals are about this process ranges on a continuum of deliberation (Nordin, Cumming, Vincent, & McGrory, 2006). At one end of the continuum, images are spontaneously generated in response to a trigger and not necessarily experienced at a high level of awareness (Nordin & Cumming, 2005b). Triggers can be internal, including performing actions, talking to oneself, a particular sensation (e.g., hearing a piece of music), or physiological responses (e.g., heart beating). External cues might involve watching others live or on videotape, as well as writing, reading, watching television, or a viewing a photograph. Most images that people experience on an everyday basis are spontaneous in nature and not generated with any particular purpose in mind (e.g., Vecchio & Bonifacio, 1997). In contrast, at the other end of the continuum is deliberate and systematic imagery practice. This type of mental activity is under voluntary control and requires skill, effort, and concentration on the part of the individual to generate, transform, inspect, and maintain images (Cumming & Hall, 2002; Cumming, Hall, & Starkes, 2005). Performers, particularly those at an elite level, will engage in regular imagery sessions that are planned in advance (e.g., what they will image and for how long) (e.g., Nordin et al., 2006; Orlick & Partington, 1988). These variations in deliberation led Cumming and Ramsey (2009) to caution researchers in their employment of "use" when describing performers' imagery. This term implies that deliberate intention was involved in the imagery process, when the images may have been unexpectedly generated.

In conclusion, the many definitions and conceptualizations of imagery have enabled us to describe this complex and multifaceted cognitive process, with particular attention paid to five key characteristics to consider in research and applied settings (i.e., modality, perspective, angle, agency, and deliberation). In the next section, we turn our attention to explaining how imagery is involved with performance by further expanding on the neuroscientific evidence introduced earlier.

How Imagery Is Involved with Performance

To elucidate how imagery can enhance performance, in this next section we introduce its hypothesized functional equivalence to motor behavior and describe the different brain processes involved. We define neural plasticity and explain how the brain changes when we learn a skill. The role played by imagery during the acquisition and execution of physical skills is discussed with specific mention to the use of pre-performance imagery to prime or stimulate subsequent movement. Finally, we explain how the degree of functional equivalence between imagery and physical performance affects imagery effectiveness.

Functional Equivalence

Imagery has long been acknowledged to benefit motor learning and performance, but few theories have satisfactorily accounted for how it works (Murphy et al., 2008). As neuroimaging techniques (e.g., PET and fMRI) have become more widely available, advancement into the underlying mechanism has been made by the detection of a degree of neural overlap between imagery and the preparation and production of actual movements. This similarity is known as *functional equivalence* because imagery is in some ways equivalent to motor behavior

(Johnson, 1982). Both share common brain areas and many of the same properties (Lotze & Halsband, 2006; Lotze & Zentgraf, 2010; MacIntyre & Moran, 2010; Munzert et al., 2009). Applying also to observation of movement (see McCullagh, Law, & Ste-Marie, 2012, Chapter 13 this volume), when we image movement, the motor and motor-related areas of the cerebral cortex are activated, including the primary motor cortex (M1), premotor areas (e.g., supplementary motor area, premotor cortex), primary somatosensory cortex, parts of the parietal lobe, and subcortical areas of the cerebellum and basal ganglia. There is some dispute over whether activation in the primary motor cortex is due to imagery or caused by inhibition of movement execution (Lotze & Halsband, 2006). It is also notable that distinctions can be made between imagery and execution in specific brain areas. For example, Gerardin et al. (2000) observed different parts of the striatum active. Even though imagery and execution share many anatomical substrates, it would therefore be misleading to suggest these were identical or to claim complete functional equivalence (Holmes & Calmels, 2008).

Functional equivalence is also evident by the physiological responses elicited during imagery mirroring actual behavior. Electromyographic (EMG) activity recorded during imagery of sporting scenarios is reflective of the muscle activity expected in the actual situation (e.g., Bird, 1984). During mental imagery of lifting a dumbbell, Guillot et al. (2007) found EMG activation in the nine upper arm muscles to correlate with actual physical movement. Further, responses generated in the muscle cells during imagery were reflective of task demands. When participants imaged lifting a heavier weight, they experienced a greater increase in EMG activity compared to imagery of a lighter weight. Imagery also produces cardiovascular and respiratory responses. Again reflecting the imaged content, Wuyam et al. (1995) reported individual's breathing frequency during imagery of themselves exercising to correlate with the imaged exercise intensity.

Further support for the functional equivalence hypothesis is by the preservation of the temporal characteristics of movements during imagery. Mental chronometric studies have showed that movement imagery duration is similar to the time it takes to execute that same movement (Guillot & Collet, 2005). A classic example involved blindfolded participants either walking or imaging walking a variety of distances. Results revealed both actual and imaged movement times increased with greater walking distance (Decety, Jeannerod, & Prablanc, 1989). This speed–accuracy tradeoff, described as *Fitt's Law*, demonstrates how imaged movement adheres to the same biomechanical rules as actual movement.

A perceptual functional equivalence also exists with imagery and like-sensory modalities (e.g., vision and visual imagery). An overlap in neural activity has been demonstrated for imagery of specific senses, including visual imagery (Kosslyn, Thompson, & Alpert, 1997), auditory imagery (Halpern & Zatorre, 1999), and olfactory imagery (Djordjevic, Zatorre, Petrides, Boyle, & Jones-Gotman, 2005). Therefore, to see with the "mind's eye," hear with the "mind's ear," and so on, the same neural processes involved in actual perception are drawn upon to recreate these experiences (Murphy et al., 2008). These findings led Kosslyn et al. to conclude that "imagery, in many ways, can stand in for a perceptual stimulus or situation" (p. 641).

Effect of Imagery on Physical Performance

After establishing the many similarities between movement imagery and actual movement, we will next consider how this co-activation leads to improvements in movement execution and sporting performance. When learning a new motor skill, various changes are thought to occur in the brain, including a strengthening of neuronal connections, the addition or removal of connections, and new cell formation. This reorganization is often termed *plasticity* and includes both short- and long-term changes (for a review, see Holmes, Cumming, & Edwards, 2010). Short-term changes appear to be a result of the strengthening in neural connections leading to changes in the borders of motor maps. For example, participants who physically performed repetitive synchronized thumb abductions and foot extensions experienced a shift in the thumb motor map toward the foot motor map (Liepert, Terborg, & Weiller, 1999). Liepert et al. explained the change, which occurred after only 120 synchronized movements, as being due to the interactions between the areas of hand and foot representation in the motor cortex. Long-term changes are thought to occur from the development and formation of synapses (Holmes et al., 2010). There also appears to be more economic neural activity following extended skill learning. Hatfield, Haufler, and Spalding (2006) proposed that skilled performers eliminate task-irrelevant cerebral cortical and subcortical connections to experience a reduction in the complexity of motor control processes organization. Thus, brain activation of a skilled performer will appear different when performing a motor skill from their set of expert skills compared to a novice performer.

All these changes in neural plasticity, both short- and long-term, are due to activation of the relevant neural areas through execution of the movement. Imagery may also contribute to brain reorganization, as suggested by Kosslyn, Ganis, and Thompson (2001), "imaging, making movements might exercise the relevant brain areas...which in turn facilitate performance" (p. 639). Only a few studies have investigated whether imaging movements leads to permanent neural plastic changes (e.g., Nyberg, Eriksson, Larsson, & Marklund, 2006). For example, Nyberg et al. (2006) found imagery of a novel finger tapping sequence to produce neuroplastic changes in the absence of physical practice, demonstrating perhaps why imagery is an effective method for the learning of skills. These important findings have also led to imagery being more commonly employed in the rehabilitation setting, particularly for helping stroke patients relearn basic movements (for review, see Page, 2010). After a stroke, individuals experience a reduction in motor cortex excitability and decreases in the size of cortical representations of paretic muscles (Liepert et al., 1998). Through repetitive, task-specific, affected-limb practice, the size of the brain regions representing that particular limb increase and functional changes occur (Dean & Shephard, 1997). Imagery is used as a supplement to this physical practice to facilitate the neuroplasticity alterations obtained by further activating the brain areas involved (Jackson, Doyon, Richards, & Malouin, 2004).

As well as leading to long-term changes in performance, the co-activation between movement imagery and execution allows imagery to provide more immediate effects to subsequent performance through its ability to "prime" the movement execution. Imagery is thought to activate and strengthen the mental representations responsible for actual performance of the movement (Murphy et al., 2008). Through this activation, the neurons responsible for movement are likely to be more prepared to correctly activate during movement execution. This type of priming has been found for the neurally similar cognitive activity of action observation; that is, observation of an action subsequently produced quicker and more accurate movements of the same action (e.g., Craighero, Fadiga, Umilta, & Rizzolatti, 1996). Less motor control research has investigated the "priming" effects imagery has on movement execution. But, within the sport setting, studies have consistently demonstrated the benefits of using imagery immediately prior to movement execution for different sport skills, including golf putting (Short et al., 2002), dart throwing (Nordin & Cumming, 2005a), table tennis (e.g., Li-Wei, Qi-Wei, Orlick, & Zitzelsberger, 1992), and tennis (e.g., Robin et al., 2007). It should be noted that, as well as facilitating performance, Nordin and Cumming (2005a) demonstrated how imagery can also prime a debilitation to performance. In their study, when participants imaged incorrectly performing a dart throwing task, they experienced a subsequent reduction in performance.

When considering together the immediate effects imagery can have on performance and those benefits occurring from changes in neural plasticity over time, this research tells us that the areas of brain activation during imagery should be as similar as possible to those active during execution of the desired outcome. In the case of observation to prime movement, a greater congruency between the prime (observed action) and subsequent execution of the action leads to better execution (e.g., Brass, Bekkering, & Prinz, 2001). The effectiveness of the observation prime is attributed to the greater overlap in areas of brain activity during the prime and the movement execution. A similar principle also applies to imagery when it serves to prime movement execution. Put another way, functional equivalence can be increased at the representational level by having images as congruent as possible to the movement to be performed. By creating greater neural overlap during movement imagery, more of the neural processes involved in movement execution will be activated and subsequently strengthened. We will explore how this may be done in the subsequent section focusing on how to maximize the effectiveness of imagery interventions.

How and What to Image: Maximizing Effectiveness of Imagery Interventions

Having a better understanding of the mechanism underlying imagery's beneficial effects on performance enables researchers and practitioners to more adequately apply imagery in a variety of settings. In the following section, we discuss the practical implications of the neuroscientific explanation presented above by reviewing the evidence for a model based upon it. The model, termed PETTLEP (Holmes & Collins, 2001, 2002), aims to improve imagery interventions by maximizing the overlap in brain activation between imaged and genuine behaviors. Our main focus is how this model informs performance

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enhancement, but we also consider PETTLEP with regards to the important role played by imagery as a rehabilitation strategy.

Further capitalizing on the neuroscientific explanation, we also examine how individual differences in imagery ability influence the impact of imagery interventions. It is apparent that high imagery ability is an advantageous attribute for performers but less clear is how this quality can be systematically improved. We propose methods for enhancing imagery ability based on cognitive neuroscience evidence and outline the burgeoning evidence for this research direction.

PETTLEP Model

To maximize the potential for overlap in neural activation between real and imaged behaviors, the PETTLEP model encourages individuals to create conditions for imagery rehearsal that mimics as closely as possibly the circumstances of physical practice or performance (Holmes & Collins, 2001, 2002). The model outlines seven elements to amplify the equivalence at the representational level between imagery and actual performance, with every element represented by a different letter of the PETTLEP acronym: *P*hysical, *E*nvironment, *T*ask, *T*iming, *L*earning, *E*motion, and *P*erspective. A definition of each element is provided in Table 11.2 and illustrated with the example of a tennis player attempting to improve return of serve via imagery (for further description elsewhere, see also Cumming & Ramsey, 2009; Holmes & Collins, 2001, 2002). The model also incorporates Lang's (1977, 1979) bioinformational theory by encouraging the elements to contain propositional information about the *stimulus* (i.e., specific details concerning the stimuli in the environment including multisensory information), *response* (i.e., the cognitive and behavioral response of the individual to this stimulus), and *meaning* (i.e., the subjective interpretation of the response) of the imaged scene. To continue with the tennis example, the player might use imagery to compare how he or she responds to easy and difficult serves and the resulting positive and/or negative feelings.

Evidence broadly supports the PETTLEP model and indicates its importance within sport settings. The physical and environment elements have been manipulated, either individually or in combination, to produce marked benefits compared to no imagery placebo controls or traditional imagery conditions (Callow, Roberts, & Fawkes, 2006; Guillot, Collet, & Dittmar, 2005; Smith, Wright, Allsopp, & Westhead, 2007; Smith, Wright, & Cantwell, 2008). Less conclusive are the findings from studies with a focus on the timing or emotion elements (Forlenza, 2010; O & Munroe-Chandler, 2008; Ramsey, Cumming, Edwards, Williams, & Brunning, 2010). The PETTLEP model explains that imaging in real time is desirable because it closely mimics actual task demands. Yet, O and Munroe-Chandler found improvements on a soccer

Table 11.2 Elements of the PETTLEP model

Element	Definition	Example
Physical	Physical nature of imagery, including body position, clothing, and sport equipment specific to task/situation.	Occupy position to receive serve while wearing tennis clothes and holding his/her racquet.
Environment	Physical environment where imagery is performed.	Perform imagery on the tennis court where match will occur.
Task	Characteristics of the task and expertise level.	Preview shots typically made in response to serve.
Timing	Temporal nature of imagery.	Perform imagery in real-time.
Learning	Imagery content evolves with learning and refinement of behavior.	Makes technical correction to shots in response to feedback.
Emotion	Affective and emotional response to situation.	Feel positive, confident, and in control of the situation.
Perspective	Visual perspective adopted (1PP vs. 3PP).	View images through 3PP analyze body position then switch to 1PP to anticipate service reception.

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dribbling task regardless of whether participants imaged in real-time, slow-motion, or beginning in slow motion and concluding with real-time imagery. Because the task was novel for the performers, slow motion imagery may have benefited their learning to the same extent as the other timing conditions (Holmes & Collins, 2001). Whether imaging in slow motion similarly affects performance of well-learned tasks still remains to be investigated, but Calmels and Fournier (2001) have shown that experienced gymnasts will vary their imagery speed depending on the situation (e.g., training vs. competition) and the function of the imagery (e.g., learning vs. managing pre-performance anxiety). Their finding suggests that the timing element likely needs to be considered in conjunction with other PETTLEP elements, particularly task and learning.

The emotions experienced in response to a performance situation are part of the network of response propositions that individuals access for more vivid and meaningful imagery (Lang, 1977, 1979). The PETTLEP model advocates the inclusion of equivalent emotions to those felt during the real-life situation. This premise was tested by Ramsey et al. (2010) by comparing soccer players who received imagery scripts describing the same stimulus information but differing in emotional content only. Both groups performed their imagery four times a week for 6 weeks and significantly improved their penalty kick performance compared to the control group who did stretching exercises. No beneficial effects were found for self-efficacy or interpretations of anxiety symptoms, but the authors recognized limitations in their choice of testing environment (i.e., a regular training session rather than a real-life match). Although there is experimental evidence indicating that individuals can elicit feelings during imagery of hypothetical competitive situations mirroring those experienced pre-competition (Cumming, Olphin, & Law, 2007; Williams, Cumming, & Balanos, 2010), interventions are still needed to substantiate whether imaging equivalent emotions benefits actual emotional self-regulation.

Because the elements interact, the value of a PETTLEP approach also increases when more elements are included in the intervention (Smith et al., 2007). For example, a full PETTLEP intervention with all seven elements was more effective for improving performance of a difficult gymnastic skill (i.e., turning straight jump on the beam) than less functionally equivalent imagery containing only the timing and perspective elements (Smith et al., 2007). As proposed by the model, incorporating all elements serves to closely approximate the real-life situation. However, Cumming and Ramsey (2009) pointed out certain circumstances, such as when ill, injured, traveling, or unable to access facilities, when it may not be practical for performers to image in the environment or be physically involved with the movement. In these situations, imagery has been advocated as a flexible substitute to physical practice for maintaining skill level, motivation, and self-confidence (Hall, 2001). To optimize functional equivalence, performers could alternatively use pictures, sounds, video clips, and sport accessories (e.g., clothing, equipment) to provide stimulus and response information for their imagery.

The amount of PETTLEP imagery also seems to matter. Wakefield and Smith (2009) found that imaging 20 netball shots three times a week was more effective than once or twice a week. Further, PETTLEP imagery is more effective when combined with physical practice (Smith et al., 2008). Experienced golfers practiced 15 shots twice per week for 6 weeks either by engaging in PETTLEP imagery only, physical practice only, or alternating between PETTLEP imagery once per week and physical practice once per week. The combined PETTLEP imagery and physical practice group significantly outperformed the other two groups at post test, with no differences found between PETTLEP imagery only and physical practice only groups. Both studies reinforce imagery as a form of deliberate practice and its value as a supplement to regular physical practice (Cumming & Hall, 2002; Hall, 2001).

An issue not yet extensively explored with PETTELP is what effect manipulating the elements has on imagery ability. As we will see in the next section, individuals vary in their ability to generate and manipulate images, and these differences will impact the magnitude of intervention effects (Hall, 1998). In the same way that PETTLEP imagery can manifest greater performance improvements, it is also likely that greater functional equivalence will also aid individuals in creating more vivid images. Gould and Damarjian (1996) suggested that holding a piece of equipment relevant to one's sport and replicating the physical movements made during actual performance (i.e., physical element) might increase imagery vividness by enabling performers to more easily recall appropriate kinesthetic sensations. Using Schwartz and Holton's (2000) concept of representational updating, Callow et al. (2006) argued further that this type of dynamic imagery will help individuals to image how one movement (e.g., the starting position) causes a second movement, thereby updating the representation held in working memory. Because imagery vividness is reflected in the richness of the representation displayed, the increased vividness resulting from the representational updating might therefore lead to performance benefits. In other words, Callow et al. suggest that imagery ability may mediate the effects of PETTLEP imagery on performance. In support, skiers in their study gave higher vividness ratings when their imagery incorporated physical and environmental elements of the PETTLEP model. Whether imagery ability does explain PETTLEP effectiveness and what role is played by elements other than physical and environmental is still to be determined by future research. However, the model does help fill a void in the literature by providing specific strategies to researchers and practitioners for enhancing imagery ability.

Research on the PETTLEP model has mainly focused on sport settings to date. Model testing is still needed with samples diverse in age (e.g., young athletes) and across a variety of performance situations (e.g., dance, music, exercise). Also warranted is the exploration of PETTLEP imagery within clinical populations for rehabilitation purposes. It is likely that enhancing the impact of imagery interventions by manipulating the seven elements will also benefit motor problems in individuals with cerebral palsy, developmental coordination disorder, and Parkinson disease; recovery of lost function and motor skill relearning following stroke or spinal cord injury; and pain management and increased strength and flexibility following athletic injury. Another critical development would be to examine what changes occur in the brain following PETTLEP imagery and to provide evidence for increased functional equivalence at the representation level.

Imagery Ability

The ability to generate and control images is present in all individuals but to varying degrees. More successful athletes, for example, report greater vividness of movement images (Roberts et al., 2008). Although frequently termed "imagery ability" in many books and journal articles, as we discuss in this chapter, imagery is also a collection of skills that are modifiable with training and experience rather than simply a general, undifferentiated fixed ability (Hall, 2001; Kosslyn, Brunn, Cave, & Wallach, 1984). We propose that although some individuals inherently find it easier to image than others, characteristics/elements associated with imaging can be honed and improved. In other words, it is possible to become more proficient in imaging. Thus, a person's capability to generate and control images is partly fixed and partly modifiable, with the former reflected by the developmental changes occurring as a result of maturation. Through the use of mental rotation tasks, it is apparent that children from as young as 5 or 6 years of age can perform movement imagery (e.g., Kosslyn, Margolis, Barrett, Goldknopf, & Daly, 1990; Marmor, 1975). But, compared to adults, young children have a tighter link between their perceptual and sensorimotor processes (Piaget, 1954). As a result, motor processes contribute to children's imagery even more so than they do to adults' movement imagery (Funk, Brugger, & Wilkening, 2005). This may be why visual and kinesthetic imagery develops in children at different rates (Livesey, 2002), with children 6 years and younger being kinesthetically poor (e.g., Ashby, 1983). An individual's capability to image does not fully develop until 14 years of age (Kosslyn et al., 1990), but it can have a substantial impact on the development of movement capabilities. Children with developmental coordination disorder have an impaired ability to generate and monitor internal models of action compared to their typically developing peers. This deficit is thought to contribute to why these children find it difficult to execute various everyday tasks such as tying a shoe lace, pouring a glass of water, or catching a ball (Wilson et al., 2004). The ability to image continues to develop across the lifespan, but from age 50 onward there is an apparent reduction in an individual's capability to image (Isaac & Marks, 1994).

COMPONENTS OF IMAGERY ABILITY

An individual's ability to image is represented by an amalgamation of components and characteristics (Morris et al., 2005). Two of the most commonly discussed are vividness and controllability (e.g., Denis, 1985; Moran, 1993; Murphy & Martin, 2002). Moran described vividness of an image as "its clarity and 'sharpness' or sensory richness," and controllability as the "ease and accuracy with which an image can be transformed or manipulated in one's mind" (p. 158). Vividness is an aspect of imagery concerned with the actual generation of the imagery, whereas controllability refers to the transformation and maintenance of the image once it has been generated. Other components include the ease with which individuals are able to generate a scenario (Hall & Martin, 1997; Williams & Cumming, 2011) and the level of emotion associated with it (Gregg & Hall, 2006). To maximize what can be viewed during imagery, we would also like to suggest the aptitude for switching between visual perspectives (1PP, 3PP) and viewing angle as another form of imagery ability. Few studies have considered this component, but a dancer interviewed by Nordin and Cumming (2005b) described her ability to switch visual imagery perspectives to meet task demands.

Another aspect of performers' imagery ability is the capacity to generate different imagery content. Williams and Cumming (2011) recently demonstrated that athletes' ease of imaging will vary depending on the content of the imagery scenarios. The athletes in their study found it significantly easier to image scenes describing the feelings associated with performing (affect imagery ability), compared to images associated with performing skills (skill imagery ability). In turn, these images were significantly easier to generate compared to images associated with performing strategies (strategy imagery ability), achieving specific goals (goal imagery ability), and mastery-type images describing remaining in control in the face of adversity or in tough situations (mastery imagery ability). Consequently, information about a performer's ability to image particular imagery content will not likely generalize to all types of imagery content that might constitute an intervention. A similarly overlooked characteristic is performers' "meta-imagery" processes, which refers to their knowledge of their imagery skills and experiences and the control they have over it (for a review, see MacIntyre & Moran, 2010). An athlete who is more aware of his imagery capabilities is likely to have a greater understanding of not only the type of imagery he finds to be most beneficial, but also self-regulate when and how he is able to maximize his imagery experiences (e.g., use the viewing perspective and angle most suitable for the task demands) to achieve desired outcomes. When asking athletes about the effectiveness of their imagery, for example, those who imaged more frequently also found it more effective for a variety of functions and easier to image (Nordin & Cumming, 2008).

THE IMPORTANCE OF IMAGERY ABILITY AND ITS ASSESSMENT

An individual's ability to create and control vivid images will influence his or her effectiveness at achieving intended outcomes (Martin, Moritz, & Hall, 1999). Interventions have been found to be more effective for individual's displaying a higher level of imagery ability when using imagery to improve motor performance (Goss, Hall, Buckolz, & Fishburne, 1986) and motivational outcomes, including self-efficacy (McKenzie & Howe, 1997). In a study to improve service return accuracy in tennis, for example, Robin et al. (2007) found imagery use in conjunction with physical practice improved performance for both good and poor imagers, but the better imagers improved more.

Because individual differences in imagery ability are important to consider, it has become common practice to screen performers prior to interventions (Cumming & Ramsey, 2009). Athletes who display poor imagery ability are usually either excluded (e.g., Callow, Hardy, & Hall, 2001) or provided with training exercises to facilitate their imagery generation (e.g., Cumming et al., 2007; Williams et al., 2010). To accomplish this task, however, researchers must have access to valid and reliable means to assess imagery ability. As Lang (1977) indicated, because imagery can only be observed by the person performing it and not by others, measuring an individual's imagery ability is not a simple process. The most common method is to use self-report questionnaires, with the two most popular and well-established being the VMIQ2 (Roberts et al., 2008) and the MIQ-R (Hall & Martin, 1997) to measure visual and kinesthetic ability to image simple movements and actions. A recent development in imagery ability measurement has resulted in the Sport Imagery Ability Questionnaire (SIAQ; Williams & Cumming, 2011). The SIAQ assesses athletes' ability to image five different sport-specific imagery types: skill, strategy, goal, affect, and mastery. Consequently, a range of measurement tools are available to meet researchers' needs.

IMPROVING IMAGERY ABILITY

Improvements in imagery ability have typically been assessed by administering questionnaires prior to and following an intervention. For example, Rodgers, Hall, and Buckolz (1991) reported significant improvements in figure skaters' visual ease of imaging after 16 weeks of imagery training. However, current imagery ability measures are not able to fully capture all the various dimensions that constitute an individual's ability to image (Cumming & Ste-Marie, 2001; Murphy & Martin, 2002). Furthermore, these different components may vary in how susceptible they are to improvement. It would appear that whereas some characteristics of the imagery process are innate and emerge through childhood and adolescence (i.e., an ability), certain aspects are more suitably classified as a skill that can be modified through various training exercises.

Greater knowledge and understanding of imagery ability components and how these can be measured will aid our understanding of which components can be improved and how this can be achieved. Despite research and various models highlighting the importance of imagery ability (e.g., Holmes & Collins, 2001; Martin et al., 1999), surprisingly little attention has been paid to how imagery ability is effectively developed. Stimulus and response training, based on bioinformational theory (Lang, 1977, 1979; Lang, Kozak, Miller, Levin, & McLean, 1980), and creating imagery in layers are approaches becoming more popular in the literature (e.g., Cumming et al., 2007; Evans, Jones, & Mullen, 2004; Williams et al., 2010). We have already suggested using the PETTLEP model as a way to enhance imagery by increasing the overlap in neural activity between movement imagery and execution.

Due to common areas of brain activation, imagery ability can also be enhanced through observation (Williams, Cumming, & Edwards, 2011). Studies have described imagery and observation as similar but distinct processes (McCullagh & Weiss, 2001), and similarly to imagery, observation is used by athletes to enhance skills, strategies, and motivational aspects of performance (Cumming, Clark, Ste-Marie, McCullagh, & Hall 2005). Video modeling has been commonly employed to aid image generation in applied settings, but research investigating the interaction between these two cognitive activities is less frequent (Morris et al., 2005). Even less attention has been paid to the potential benefits of observation on imagery's effectiveness, but evidence suggests a combination of imagery and observation in the absence of physical practice also appears to produce greater performance enhancements compared to imagery on its own (e.g., Atienza, Balaguer, & Garcia-Merita, 1998). By observing a model, an individual receives a clear and vivid instruction of what he or she is required to image (Lang, 1979). Videos of the self or others performing also include specific sensory information to incorporate into an image to improve its quality (Gould & Damarjian, 1996).

Investigating whether observation could serve as a prime to imagery ability, Williams et al. (2011) asked individuals to complete the MIQ-3 (the MIQ-R was revised by these authors to separate visual imagery into 1PP and 3PP, resulting in three subscales including kinesthetic imagery) under four different conditions: (1) *movement prime* (the MIQ-3 was completed in its usual format, in which participants physically perform the movement before imagining the scenario and then rate the ease with which they are able to image the movement); (2) *external observation condition* (same format as the movement prime condition but movement execution was replaced by observation of the movement from an external observation perspective); (3) *internal observation condition* (same format as the external observation condition but the observation was from an internal perspective); and (4) *image-only condition* (the MIQ-3 was completed without prior movement or prior observation; participants simply imaged the scenario and rated the ease with which they were able to do this). Results revealed that MIQ-3 scores were significantly higher during all three prime conditions compared to the image-only condition. Observation was successful in priming and enhancing imagery ability, but for visual imagery, the imagery perspective needed to be congruent with the observation perspective adopted. That is, both the imagery and observation needed to be done from the same perspective for maximum benefit (i.e., 3PP observation and 3PP imagery or 1PP observation and 1PP imagery).

Beyond Skill Performance: Other Outcomes of Imagery

Most of this chapter has been concerned with the effects of imagery on motor skill performance, but many other beneficial effects can be achieved from imagery relating to motivation, attention, arousal and emotional control, confidence and self-efficacy, problem-solving, memorization, planning and creative thought, reviewing and evaluation, strength, flexibility, and healing (Bernier & Fournier, 2010; Munroe et al., 2000; Murphy et al., 2008; Nordin & Cumming, 2005b, 2008; Ranganathan, Sieminow, Liu, Sahgal, & Yue, 2004). Within the applied model of imagery use (see Figure 11.1; Martin et al., 1999), these outcomes mainly fall under three major categories: facilitating the learning and performance of skills and strategies; modifying cognitions; and regulating arousal and competitive anxiety.

This model explains that, as governed by the situation, athletes should image the affective, behavioral, and cognitive changes they desire to achieve. In other words, "what you see is what you get." A number of theoretically and conceptually meaningful relationships have emerged between types of imagery and the outcomes achieved (for a review,

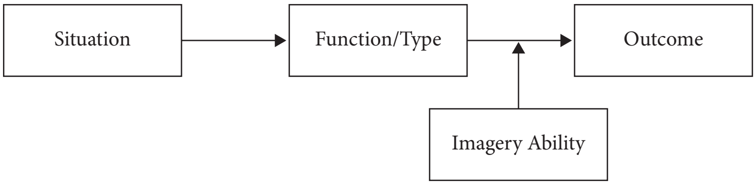

Figure 11.1 Applied model of imagery use.

see Cumming & Ramsey, 2009). For example, skill-based images have led to skill learning (e.g., Nordin & Cumming, 2005a), goal-based images have increased motivation (e.g., Martin & Hall, 1995), and confidence-based images have enhanced beliefs about one's abilities (e.g., Callow et al., 2001). Thus, it appears beneficial to match imagery content to anticipated outcomes.

Growing evidence also suggests that imagery will bring about other unintentional results. That is, there is more to imagery content that what meets the eye (Nordin & Cumming, 2005a; Short, Monsma, & Short, 2004). Indeed, numerous investigations have found more than one outcome resulting from using a type of imagery (e.g., Callow & Hardy, 2001; Callow et al., 2006; Callow & Waters, 2005; Evans et al., 2004; Nordin & Cumming, 2005a, 2008). For example, skill-based imagery can also serve as a source of performance accomplishment to increase self-efficacy beliefs (Nordin & Cumming, 2005a), and both goal-based and confidence-based images can improve skill learning (Martin & Hall, 1995; Nordin & Cumming, 2005a).

Rather than content determining what outcomes are achieved, the benefits of an imagery intervention depend instead on the function of this content for the individual (Callow & Hardy, 2001). For example, a dancer might use imagery to feel more confident (function), and the result of this imagery might be increased confidence (outcome). Paivio (1985) proposed that imagery has both cognitive and motivational functions, and each operates at specific and general levels. The resulting 2 × 2 framework (cognitive specific, cognitive general, motivational specific, and motivational general) formed the basis of early explorations into why athletes image (Salmon et al., 1994) and led to the Sport Imagery Questionnaire (SIQ; Hall, Mack, Paivio, & Hausenblas, 1998). As part of the questionnaire's validation, motivational general was further divided into arousal and mastery function, and all five measured functions represented by different subscales. What has led to subsequent confusion was the decision to define the imagery functions by their closely related content, with "what" athletes are imaging considered interchangeable with "why" (for discussions on this issue, see Cumming & Ramsey, 2009; Murphy et al., 2008). Hall (2001) has since argued that function should not be presumed by the content of athletes' imagery. For example, the SIQ item "Before attempting a particular skill, I imagine myself performing it perfectly" may be done for its intended cognitive specific function (e.g., to develop the skill), but also can serve motivational specific (e.g., to preview goal achievement), motivational general-arousal (e.g., to ease worries and tension about progress), and motivational general-mastery (e.g., to build confidence) functions for the performer. Alternatively, it is possible that the respondent does not consciously generate this image for any specific purpose. Instead, the image might occur spontaneously in response to a cue (Murphy et al., 2008; Nordin et al., 2006).

Noting the potential ambiguity caused by equating content with function, Short et al. (2004) modified the SIQ to ask athletes to indicate why they used each type of imagery listed on the questionnaire by choosing from five functions: to assist the learning and performance of new skills or strategies, or to effect motivation, arousal/anxiety, or confidence. All imagery types were found to serve their designated functions, but five of the 30 items were perceived as serving an unintended function, and all items were perceived as serving several functions to some extent. Other investigations have also confirmed that performers employ the same image for different reasons, thus a conceptual distinction is now made between the terms "type" and "function" (Bernier & Fournier, 2010; Cumming & Ramsey, 2009; MacIntyre & Moran, 2010; Murphy et al., 2008; Nordin & Cumming, 2005b, 2008). The consensus is that *type* denotes what performers' image and *function* explains why. With this difference in mind, the subscales of the SIQ are likely best considered imagery types rather than functions.

Revised Applied Model of Deliberate Imagery Use

With clarification made to type and function, we now need to separate them in the applied model of

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imagery use (Martin et al., 1999). We agree with Fournier, Deremaux, and Bernier (2008) that function rather than type should form the central feature and propose a revised model (Figure 11.2) to build on their thinking and those of others (e.g., MacIntyre & Moran, 2010; Murphy et al., 2008). Since its inception, the applied model has been embraced by researchers and practitioners alike as a simple, practical, and testable framework. It provides specific predictions and guidance for the selection of variables to include in experiments. The model also ensures that interventions are designed with specific goals or outcomes in mind. There is also diverse evidence favoring its basic tenets (Cumming & Ramsey, 2009).

The revised model embraces these strengths and remains true to its original by representing "where," "when," and "why" performers use imagery to achieve desired outcomes. It also demonstrates how this is influenced by the performers' capability to image. Additionally, we have answered Martin et al.'s call to elaborate on the model by adding "who," "what," and "how" to its components. But probably the most important refinement we have made is to acknowledge personal meaning as the link between imagery function and type. Although we refer to performers (e.g., athletes, dancers, musicians), this model has broader application to the same clinical populations mentioned in the PETTLEP imagery section. We thus encourage testing of the revised applied model in a range of settings, including exercise, dance, and rehabilitation, and with different populations. For several model components, we also discuss how these can be informed by elements of the PETTLEP model to maximize imagery effectiveness further. An intervention combining both models will enable individuals to perform functionally equivalent imagery that is personally meaningful to their goal achievement (Cumming & Ramsey, 2009).

Why, What, and Personal Meaning

Our model specifies that the function (rather than type) of performers' imagery will determine affective, cognitive, and behavioral outcomes via the content generated. Consistent with Martin et al.'s conceptualization, these relationships will be theoretically and conceptually meaningful, thus allowing for specific predictions and testing. A key difference in our thinking is that the function will be served mainly, but is not restricted to, content reflecting this function. This allows for imagery types that do not fit within Paivio's cognitive and motivational imagery framework to be included, as well as the combination of imagery types (e.g., skill-based and confidence-based imagery might be combined to serve the function of feeling more confident of performing a certain skill consistently well). We also presume that performers' are imaging with some degree of conscious intent or deliberation in order for the imagery to serve a function. Spontaneous imagery will generate content and achieve outcomes but will be experienced with no particular function in mind.

In many circumstances, the performers' imagery function will match the type of imagery used to achieve the desired outcome. However, as already pointed out, these relationships are not always straightforward as predicted in the original applied model. Imagery is a highly personal experience, and what is imaged can carry different meanings to different individuals, as has been emphasized in some imagery models, notably Ahsen's triple-code model

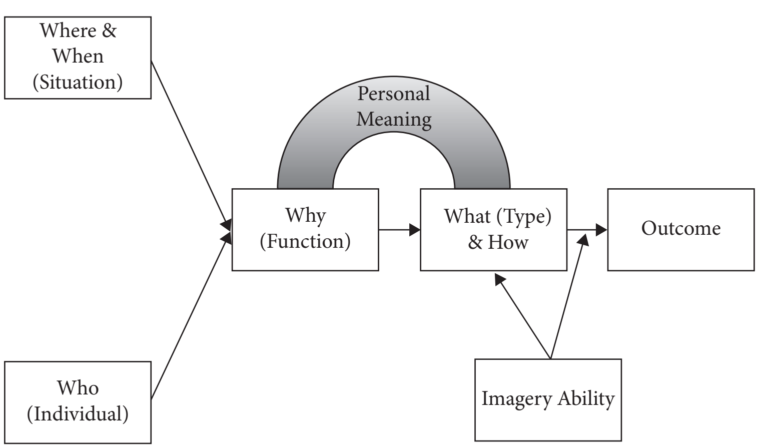

Figure 11.2 Revised applied model of deliberate imagery use.

(Ahsen, 1984) and Lang's bioinformational theory (Lang, 1979). Although mentioned by Martin et al. (1999) in their development of the original applied model, this concept is absent from the framework. We consider the personal meaning attached to the imagery experience as the key for determining what content corresponds to function. Thus, in our revised model, we portray personal meaning as a bridge between function and content. To illustrate why, in their case study of an elite rugby union player, Evans et al. (2004) describe his preference for technical and tactical images to increase his confidence, control anxiety levels, and prepare effectively for matches rather than the affective- or mastery-based content prescribed by the "what you see is what you get" principle.

Consequently, a key consideration when developing imagery interventions is not only the desired outcome, but what type(s) of imagery will serve the function for the intended person. For this reason, Short and Short (2005) advocate deciding on the imagery function first, before determining with the performer what content will facilitate it. Although more time-consuming for the researcher/practitioners, the pros of finding out this information will likely outweigh the cons. When an intervention is personalized to the specific needs of the performer, it will carry greater weight and he or she will likely find it more enjoyable and easier to perform (Cumming & Ramsey, 2009). In doing so, the imagery function will not only correspond theoretically to intervention goals, but the content will also be meaningful for the individual.

WHERE, WHEN AND WHO: IMAGERY ANTECEDENTS

The situation is retained in the revised applied model as having a direct influence on the reasons that performers image (Martin et al., 1999). This component encourages consideration for where and when imagery takes place when planning an intervention, and performers report doing so at diverse times and locations (Munroe et al., 2000; Nordin & Cumming, 2005b). From PETTLEP imagery research, it is already established that being in the environment where the actual or intended behavior will occur maximizes imagery effectiveness (Callow et al., 2006; Guillot et al., 2005; Smith et al., 2007). We also include the individual (i.e., who) as another antecedent composed of factors such as the person's age, gender, experience, disposition (e.g., achievement goal orientation, self-determination, perfectionism), and general ability to image. This is not an exhaustive list but provided as a starting point for researchers to develop testable predictions. For example, knowing that an athlete is high in ego orientation might explain why she perceives images of herself outperforming others to be motivational (Harwood, Cumming, & Fletcher, 2004).

HOW TO IMAGE

When planning an imagery intervention or experiment, it is also important to think about how the performers will image. Because this concept is so closely related to what performers' image, they are represented together in Figure 11.2. As discussed at the outset of the chapter, the imagery process will be characterized by modality, perspective, angle, agency, and deliberation. Qualitative research (Munroe et al, 2000; Nordin & Cumming, 2005b) also informs us of other characteristics, such as the amount, duration, speed, vividness, and color of the imagery. The PETTLEP model elaborates on how external or internal cues can provide individuals with a starting point for image generation. These triggers can serve a reminder to prompt greater image use and adherence to the intervention. Also necessary to consider is how performers can develop their images by adding clarity and layers of detail to make fuzzy or simple images more vivid or complex (Calmels, Berthoumeiux, & d'Arripe-Longueville, 2004; Evans et al., 2004; Nordin & Cumming, 2005b). Finally, the degree to which performers approach their imagery in a deliberate, structured, and planned way (e.g., what they will image and for how long) constitutes another aspect of this component of the revised applied model.

IMAGERY ABILITY

The last component of the model is imagery ability, which we propose will directly influence what and how a person images. Individuals vary in their ability to image different types of cognitive and motivational content (Williams & Cumming, 2011). For example, some people might find it easier to image emotions than skill execution. When it comes to selecting content to serve a particular function, it is likely that people will choose imagery content they find easier to generate. In support, Williams and Cumming (~~in press~~) found that the ability to image certain content significantly predicted how frequently individuals use imagery of that content. Imagery ability may also similarly influence the modality, perspective, angle, or agent of behavior imaged, as well as other characteristics such as the amount, duration, speed, and color of the imagery. This is because individuals who find it easier to image in a certain way (e.g., in real time from a first-person perspective) may also be more likely to use this preference to determine how they image.

Because imagery ability will influence what and how individuals image, it will also indirectly affect what outcomes are achieved (i.e., mediation). Take, for instance, the visual imagery perspective adopted. Individuals who are unable to form images from a certain viewpoint (e.g., 3PP) will correspondingly be unable to generate certain types of content (e.g., viewing what one looks like performing a movement from behind or the side). If a certain visual perspective is more desirable for the task (e.g., form-based movement), the outcome achieved by the imagery might therefore be hampered by the individual's lack of ability to image from that perspective.

In keeping with Martin et al.'s (1999) original conceptualization, imagery ability is also considered to moderate the relationship between what performers' image and the outcomes achieved (as reflected by the dashed line in Figure 11.2). Whether imagery ability is best considered a mediator, a moderator, or both, requires further testing. When the applied model was published, only movement imagery ability had been tested as a moderator between skill-based imagery and performance outcomes. Mainly due to limitations in imagery ability measurement (Hall, 1998), research has been slow to test whether this relationship also holds true for other types of imagery and other outcomes (e.g., Cumming, 2008; Nordin & Cumming, 2008). However, the available data strongly point to individual differences confounding imagery interventions, thus indicating a need to measure imagery ability as part of screening procedures and to assess changes occurring throughout. Also to be considered are other components to imagery ability mentioned earlier in this chapter, including imagery perspective and angle switching, as well as meta-imagery processes. Finally, we encourage researchers to include measurements of imagery ability before, during, and after interventions to measure any improvements made.

Conclusion

In this chapter, we have described imagery as both a fundamental cognitive process for producing motor actions and a performance-enhancing technique widely used by athletes and dancers. Using Holmes and Calmels' (2008) definition as the basis, we focused on key characteristics of the imagery and the imagery process. Research from the field of cognitive neuroscience helps explain how imagery is involved with motor skill performance, including the concepts of functional equivalence and neural plasticity, and helps guide the planning of more effective interventions through application of the PETTLEP model (Holmes & Collins, 2001). We also discussed the role played by imagery ability and made suggestions for how this skill can be trained. Finally, we described other imagery outcomes and offered a revised applied model of imagery use. Although our chapter has discussed on many contemporary issues, challenges still remain for imagery researchers, and we touch on these in the final section.

Future Directions

HOW PERSONALIZED DO IMAGERY INTERVENTIONS NEED TO BE?

Applied sport psychologists recommend the need to plan the content of imagery interventions with the individual needs of the performers in mind. Particularly within consulting sessions, the function and content of imagery are elicited through discussions about personally meaningful stimulus and response propositions. This information provides material for writing imagery scripts or developing cues to trigger the imagery process. Not to be overlooked is also the performers' preferences for how to image, which could form part of the intervention goals (e.g., developing greater vividness or the ability switch perspectives). In other words, it is possible to individualize every aspect of the intervention from content to delivery (Cumming & Ramsey, 2009). However, it is not always feasible or appropriate to do so. For example, in experimentally designed studies, researchers may choose to test theoretical hypotheses by providing different sets of instructions to participants. Currently unknown is what effect these research-driven instructions have on imagery compared to the more participant-driven scripts characteristic of consulting work or field-based interventions. A solution to this problem may fall in the middle of these two extremes, using procedures for partially individualizing imagery by asking participants to provide stimulus information based on their past experiences combined with researcher-driven response information (e.g., Cumming et al., 2007; Williams et al., 2010).

HOW DO WE KNOW SOMEONE IS IMAGING?

Due to imagery being a covert and subjective experience, imagery researchers have long been troubled by the problem of knowing whether a person is actually imaging, and, if they are imaging, whether their accounts about their imagery experiences are accurate. These limitations have created doubts about explicit forms of imagery (i.e., conscious internal representations of behavior) and the use of self-report measures (e.g., questionnaires, mental chronometry). It may also be difficult for participants to provide precise verbal reports of a primarily nonverbal experience. An alternative approach has been to examine implicit forms of imagery (i.e., nonconscious internal representations of behavior) using paradigms such as mental rotation tasks. Different types of stimuli are presented on a computer screen (e.g., pictures of hands and feet in different views and angular orientations) and participants are asked to make laterality judgments (e.g., Is it a right or left foot?). The assumption is that participants will use imagery to mentally rotate the body part to determine what judgment to make. Although this approach provides a more objective measure, it does not appear to tap the same type of imagery ability as measured through self-report methods (Lequerica, Rapport, Axelrod, Telmet, & Whitman, 2002). It is also possible that participants are using a strategy other than imagery to form their decisions. A growing trend is to combine self-report with other indices of the imagery experience, including physiological and neurophysiological measures (Guillot & Collet, 2005). For example, changes in the physiological state of the imager can be assessed by recording heart rate and stroke volume to indicate that response information is being included in the imagery (Cumming et al., 2007; Williams et al., 2010).

ESTABLISHING THE MOST EFFECTIVE METHODS FOR IMPROVING IMAGERY ABILITY

As we emphasized throughout the chapter, imagery ability is considered very much modifiable through training and experience, rather than being a solely fixed attribute. Research is starting to establish various methods that are capable of facilitating and improving an individual's proficiency at imaging imagery, and the next logical step would be to compare these methods to determine which is most effective for developing different imagery ability components. For example, observation may serve as a better method to improve movement imagery ability when the focus is on the correct execution of the movement, whereas layering exercises may be more beneficial when the imagery is more focused on specific feelings and emotions associated with the image. Another important point to consider is whether these techniques can bring about any retention effects or whether they simply act as a prime by facilitating neural activation during the imagery process.

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