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The Nature, Measurement, and Development of Imagery Ability

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Abstract

This introduction to a special issue of Imagination, Cognition and Personality discusses how imagery ability is conceptualized, measured, and developed within sport and exercise sciences. Drawing from the model of imagery ability in sport, exercise, and dance, we explain that imagery ability is best understood not as a single undifferentiated general ability but as a complex multiprocess, multisensory, and multidimensional set of capacities. We argue that a more nuanced way of understanding imagery ability and its subcomponents should guide the development and selection of appropriate measurement tools and training methods. Finally, we introduce the four articles that make up this special issue on imagery ability, which collectively present a range of approaches for progressing this area of research further.

Keywords

imagery, imagery ability, measurement, training

As a "central pillar of applied sport psychology" (Morris, Spittle, & Watt, 2005, p. 344), mental imagery is considered an important mental technique for athletes

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to master. Its frequent and systematic use is a characteristic of talented performers and long known to distinguish successful athletes from those who are less successful (Cumming & Hall, 2002; Kosslyn, Brunn, Cave, & Wallach, 1984; Rees et al., 2016). There is also increasing recognition that imagery can be used to promote and maintain physical activity behavior (Weibull, Cumming, Cooley, Williams, & Burns, 2017) in a range of groups, from children and young people (Tobin et al., 2017) to older adults (Giacobbi et al., 2014). Regardless of the context or who is undertaking the imagery, a factor known to influence it's effectiveness is an ''individual's capability to form vivid, controllable images, and retain them for a sufficient time to effect the desired imagery rehearsal'' (Morris et al., 2005, p. 37).

It was Galton (1880) who first observed that the ''detail and clarity with which individuals experience mental imagery'' (p.304) will involve an individual difference gradient across any given population. He operationally defined this as *vividness*, which refers to an individual's capacity to imagine. A long-standing assumption for researchers exploring imagery in sport and exercise is that this capacity for imagery is not an undifferentiated general skill, but rather it is a skill that can be parsed into a series of subattributes (Kosslyn et al., 1984). Theoretical accounts of mental imagery have, however, often remained either vague or unresolved regarding the specific attributes of imagery ability. They neither refute nor eliminate the importance of imagery ability as a psychological construct (cf. Kosslyn, Sukel, & Bly, 1999). It is our assertion, therefore, that authors referring to imagery ability should make every effort to clarify their intended meaning for this term. To move the evidence base forward, it is time for our field to sharpen the operational definitions of imagery ability, which in turn will help us to identify the most effective tools to both measure and develop the core characteristics.

Given the importance placed on imagery use and its popularity within the sport and exercise sciences, it is surprising how little attention imagery ability has received within this discipline. Putting imagery ability into the spotlight, this special issue of Imagination, Cognition and Personality aims to unravel and clarify imagery ability within the movement domain. We begin by discussing how imagery ability is conceptualized, measured, and developed, guided by the model of imagery ability in sport, exercise, and dance (MIASED; Cumming, Williams, Weibull, & Cooley, 2012). Four articles are then presented, which collectively challenge traditional approaches to conceptualizing imagery ability. This is by highlighting, for example, the need for imagery training programmes to account for a range of variables that have previously not been experimentally controlled for, including sleep quality, amount of physical activity, and possible longitudinal changes in imagery ability over the sporting season. A further contribution in this special issue is the proposal for an exciting new and well-substantiated objective behavioral measure of imagery ability.

Nature of Imagery Ability

Our ability to mentally image, as illustrated by Morris et al.'s (2005) definition earlier, is a complex cognitive process that involves not just the way we generate images but also how we maintain images over time. Inspection and transformation are two additional processes not covered in this definition that also help us to understand the nature of imagery ability (Kosslyn, Behrmann, & Jeannerod, 1995; Kosslyn, Thompson, & Ganis, 2006). Each of these four main processes can be explained as the following:

1. Image generation: It involves creating an image based on retaining sensory information or stored information in long-term memory in the absence of perceptual stimuli (Kosslyn et al., 1995). If an ice-skater was asked to describe the ice rink where an event had been previously held, she would bring an image of the venue to their mind to answer the question. Kosslyn (1987) explained that this image is a transient representation in the skater's short-term memory, which is generated from sensory information encoded during the real-life experience and stored in long-term memory.
2. Image inspection: It involves scanning the whole or parts of an image, interpreting its patterns, and extracting information (Kosslyn et al., 2006). The ice-skater might scan the whole rink in her mind's eye or zoom in or out of the image to see certain details of the ice rink. Although distinct from image generation, these two processes work in tandem together. The act of inspecting an image may lead the skater to generating further details of the ice rink.
3. Image transformation: It involves changing either the content or characteristics of an image. As explained by Cumming and Williams (2013), imagery content refers to what is being imaged (e.g., skills, strategies, goals), whereas characteristics refers to how the imaged content is experienced (e.g., agency, angle, modality, perspective). The ice-skater could alter the appearance of the ice rink or other details such as the air temperature or ice conditions or placement of the judges.
4. Image maintenance: It takes time to generate, inspect, and transform images, and therefore images must be maintained for these processes to be carried out and the desired outcomes achieved. The ice-skater may hold on to the image of the ice rink to build a sense of excitement toward competing at this venue again in the future or to remember the feelings of success associated with a previous performance. To do so, she must constantly reactivate the memory representation because images can fade as soon as they are formed (Kosslyn et al., 2006).

In this account, our capacity to image is not a single undifferentiated ability but is instead best understood as multiple processes that can vary within and

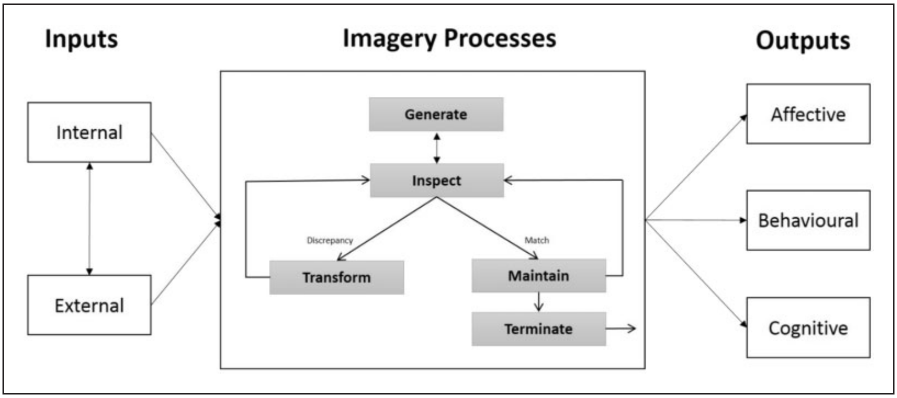

Figure 1. Model of imagery ability in sport, exercise, and dance (Cumming et al., 2012).

between individuals. To explain how these processes interact during deliberate and conscious forms of imagery, Cumming et al. (2012) developed the MIASED (Figure 1). The MIASED is based on computational approaches to understanding the cognitive systems and processes involved in imagery (Kosslyn, 1980, 1994; Kosslyn et al., 2006) as well as relevant models from the field including the PETTLEP model (physical, environment, task, timing, learning, emotion, and perspective; (PETTLEP; Holmes & Collins, 2001), the revised applied model of deliberate imagery use (Cumming & Williams, 2013), and the neurocognitive model of imagery in sport, exercise, and dance (Murphy, Nordin, & Cumming, 2008). Although Kosslyn's theoretical and empirical work has mainly focused on visual imagery, he has also recognized the application of these ideas to other sensory modalities and motor imagery (e.g., Kosslyn et al., 1995). The MIASED therefore aims to (a) provide a description of multisensory imagery (e.g., visual, kinesthetic, auditory, haptic, gustatory, etc.) processes in a systematic and interpretable way (Kosslyn, 1987); (b) guide the development and selection of appropriate measurement tools for assessing an individual's ability to carry out these processes; and (c) inform the development and selection of methods for developing and improving imagery ability. That is, the model can inform decisions made in the planning and evaluation of interventions and, by doing so, can provide both researchers and practitioners with a better conceptual understanding of the imagery process. Next, we describe the three main components of the MIASED model, which relate to the inputs, the imagery process, and the associated outputs.

Inputs

The MIASED proposes that images originate internally from our stored memories, which may or may not have been initially stimulated by an external perceptual cue (Murphy et al., 2008; Pearson, Deeprose, Wallace-Hadrill, Burnett Heyes, & Holmes, 2015). Most individuals will have the capacity to revisit previous experiences or preview upcoming ones by combining information from different sources, including imaging novel scenarios and events that have not previously been experienced (e.g., inventing a gymnastics move or achieving a personal best time in swimming) or are not physically possible (e.g., turning into a swan when performing the ballet Swan Lake). Indeed, images can be novel combinations of movements, objects, or characteristics encoded at different times and places (Kosslyn et al., 1995). For internal image generation, our working memory plays a role in retrieving the information from long-term or short-term memory (Murphy et al., 2008; Pearson et al., 2015). Sensory cues external to the person may also stimulate the imagery process, whether this is observing the performance of oneself or another athlete on video, wearing sports clothing or holding a sports implement, hearing music or sounds related to sport, and so on (Anuar, Cumming, & Williams, 2016; Carson & Collins, 2011).

Imagery Processes

Once stimulated, the image is generated in working memory, with the visuospatial sketchpad involved with visual and spatial information and the phonological loop involved with auditory information (Baddeley, 1986). A skilled imager can check whether the generated image matches what was intended or desired image through inspection. For example, a basketball player might be able to describe the visual perspective and angle being used to view an image of a successful layup shot at a key point during a game (i.e., the desired image). If it is a match between the generated and desired image (i.e., successful layup shot), or after regenerating the transformed image (i.e., altering the content and characteristics until the desired imaged is achieved), the player would continually regenerate the image content and characteristics for a period of time to receive the desired benefits (e.g., confidence to perform shot under game pressure). If there is a discrepancy with the intended or desired image, the imager may attempt to transform the image by manipulating or restructuring its content or characteristics. The basketball player may mentally rotate the image to view the shot from a different angle or modify the speed or distance of his or her approach until an accurate representation of a successful shot is achieved. The transformed image is then reinspected. If it matches with the desired image, the imagery process carries on with maintenance and finally, the image fades or is terminated.

This sequence can be very brief for simple images but lengthen for more complex or detailed images. Based on behavioral experiments, Kosslyn (1994) explained that a visual image will rapidly decay, with the average duration being 250 ms. To experience an image beyond this period, the imager must constantly reactivate or regenerate the image.

Outputs

The imagery process can result in one or more outcomes, which can broadly be categorized as affective, neurocognitive, and behavioral in nature. Affective outcomes may include reaching and maintaining optimal arousal levels and emotions, whereas examples of cognitive outcomes would be self-efficacy, confidence, reappraising symptoms of anxiety, and staying positive after making a mistake. Finally, behavioral outcomes would include learning or refining motor skills, correcting a bad technical habit, increasing strength, rehabilitating following injury, and so on (Braun et al., 2013; Schuster et al., 2011; Tod, Edwards, McGuidan, & Lovell, 2015). By achieving these outcomes, imagery can effectively influence an individual's sport or exercise performance, their personal development, as well as their well-being.

Our ability to carry out image generation, inspection, transformation, and maintenance can be described by different attributes; that is, imagery ability is multidimensional as well as involving multiple processes and multiple senses. Within sport and exercise sciences, we are typically concerned with the five dimensions of accuracy, ease of generation, controllability, duration, or vividness (Denis, 1985; Morris et al., 2005). Accuracy reflects the exactness of the imaged representation, with more accurate images indicative of an individual's capacity to generate images. Ease typically refers to how easy or difficult it is to generate images but can also relate to the other three imagery processes. For example, an exerciser may find it easy to generate an image of themselves doing a certain aerobic dance step but then find it difficult to scan the image for details, transform, or maintain it for the desired amount of time. The latter would also be reflected in the duration or amount of time an image is clearly maintained from the point of generation until it disappears or is terminated. Controllability is the ease and accuracy with which an image can be transformed or manipulated, reflecting an individual's ability to influence imagery content. Finally, vividness describes the clarity, sharpness, and sensory richness of the image (Runge, Cheung, & D'Angiulli, 2017).

The MIASED encourages us to consider how these five dimensions interact and change with different imagery processes. For example, a rugby union player may find it easy to vividly generate the opening play of a match, but the richness may fade as he or she attempts to maintain this image after the drop kick hits the ground. These different ways of describing the imagery experience suggests that imagery ability is multidimensional as well as involving multiple processes.

Measurement of Imagery Ability

As a covert process that can only be truly observed by the imager, a challenge for researchers has been to measure imagery ability in a valid and reliable way. Both subjective and objective measurement approaches are available. Subjective methods involve gathering information about explicit imagery experiences using questionnaires, interviews, or other self-report methods, whereas objective measures can tap imagery more implicitly using behavioral, physiological, or neural measures (for more information on these measurement approaches, see Collet, Guillot, Lebon, MacIntyre, & Moran, 2011; McAvinue & Robertson, 2007). As neither approach in isolation would capture the full multidimensional nature of imagery ability, a combined approach has been advocated by Collet et al. (2011), who proposed the motor imagery index (MII). The MII is calculated based on a self-report measure (e.g., the Movement Imagery Questionnaire-Revised [MIQ-R]; Hall & Martin, 1997), mental chronometry (e.g., the temporal congruence of real and imaged movement), and physiological indices of the autonomic nervous system (e.g., cardiac and electrodermal activity).

Although the MII requires further validation, it offers a promising way to overcome some of the limitations associated with the use of any one measurement approach. Encouragingly, evidence is accumulating in favor of combing different imagery ability measures (Guarnera, Stummiello, Cascio, & Di Corrado, 2016; Marchesotti, Bassolino, Serino, Bleuler, & Blanke, 2016; Williams, Guillot, Rienzo, & Cumming, 2015). A potential limitation of the MII, however, is that it does not yet capture each of the four imagery processes. Currently, the proposed indices would tap image generation (MIQ-R) and maintenance (mental chronometry) processes but not inspection or transformation. A revised version of the MII may therefore be required to include additional measures, such as mental rotation, to more fully assess an individual's imagery ability. But, as Collet et al. (2011) rightly point out, integrating these different indices requires researchers and practitioners to have the knowledge and skills to collect, process, and analyze the different types of data. Alternatively, researchers may seek to develop more efficient imagery ability measures that simultaneously capture multiple processes and dimensions.

Until such a measure is available, a recommendation based on the MIASED for researchers and practitioners is to be purposeful when selecting the relevant approach and consider whether it adequately captures the imagery process or dimensions of interest to the study. If an intervention is intended to improve the ease of generation or the vividness when representing movements from different visual perspectives and modalities, the MIQ-3 (Williams et al., 2012) or Vividness of MIQ-2 (Roberts, Callow, Hardy, Markland, & Bringer, 2008) would be suitable, respectively. Imagery is also a domain-specific skill, however, which means these general measures will be less equipped to capture the more nuanced and specific features imagery abilities (Di Gruttola & Sebastian, 2017). Thus, if an intervention is intended to improve the ease with which athletes generate skills, strategies, goals, affect, or mastery images, a more appropriate tool would be the Sport Imagery Ability Questionnaire (SAQ; Williams & Cumming, 2011). As for other image processes, a mental rotation task

(Wexler, Kosslyn, & Berthoz, 1998) or subtraction of parts tasks (Guarnera et al., 2016) are methods for assessing image inspection and transformation ability, whereas the duration of image maintenance may be best captured through the use of mental chronometry (Collet et al., 2011).

Looking beyond this special issue, we call on imagery researchers to more comprehensively review and map existing measurement approaches and paradigms across the imagery processes before more explicit guidance can be provided. Such a mapping exercise will likely reveal current gaps in imagery ability measurement within sport and exercise sciences to be addressed by future research.

Development of Imagery Ability

Some individuals, particularly those new to imagery rehearsal, may find it difficult to maintain an image for even a few seconds because it requires mental effort and attention. For this reason, and reiterating the recommendation made by Orlick (2015), a guideline is to begin with short bouts of imagery rehearsal, which can gradually increase in duration over practice. Aiming for high-quality imagery, the MIASED may guide attention toward developing each of the imagery processes. Before an image can be maintained, for example, the imager would initially need to develop their ability to generate images. Practice alone will likely bring about improvements in these different processes. However, systematic efforts to improve (i.e., more deliberate forms of imagery practice; Cumming & Hall, 2002) would maximize these efforts further.

A technique for developing the different imagery processes is Layered Stimulus Response Training (LSRT; Cumming et al., 2017), based on bioinformational theory (Lang, 1977, 1979). LSRT is intended to help individuals more easily generate and control their imagery experience by breaking down different elements of an image and then bringing them together in progressive layers. These elements are stimulus (i.e., information about the situation), response (i.e., information about the physical and emotional responses to the situation), and meaning (i.e., how the response to the situation is interpreted by the individual) information. Through cycles of imaging, reflecting on, and further developing what was imaged, LSRT directs focus toward each of the four imagery processes. By doing so, the individual may become better able to draw upon different sources of information to generate their images, scan and alter their images to make it more vivid and realistic, and direct mental focus to retain this information for the desired length. Compared with imagery rehearsal alone, LSRT consequently promotes better awareness of the imagery experience and the development of metacognitive skills. In support, Williams, Cooley, and Cumming (2013) found that novice golfers receiving LSRT during a 4-day imagery intervention improved both self-reported imagery ability as well as performance of a golf-putting task (despite no physical practice). However, LSRT has not yet been tested with wider range of imagery ability measures, and replication with different types of tasks is also warranted.

In addition to LSRT, there are different aids to the imagery process that can also be used to improve imagery ability. One of the most traditional ways to cue an imagery experience is by using a script, which is tailored to the individual for maximum effectiveness (Williams, Cooley, Newell, Weibull, & Cumming, 2013). Scripts can be delivered in a range of formats (e.g., listening to a prerecorded audio script, hearing sport-specific sounds, seeing a picture). Observing oneself or another person just prior to imaging is another method growing in popularity. Research shows that prior observation can improve the ease of imaging in both visual and kinesthetic modalities (e.g., Battaglia et al., 2014). However, it is important for the demonstration to be filmed in the same visual perspective as that adopted by the imagery (Williams et al., 2013). Holmes and Collins' (2001) PETTLEP elements can also be used to prime the imagery experience. Making small gestures or *walking through* performance, standing or adopting the starting position, holding or touching an implement related to the sport, and imaging in the environment where the real-life experience takes place would all be possible aids (e.g., Anuar et al., 2016; Bisio, Avanzino, Ruggeri, & Bove, 2014).

Recently, Anuar, Williams, and Cumming (2016) compared the effectiveness of PETTLEP imagery with prior observation and more traditional forms of imagery (e.g., imaging in a quiet room). The results showed that higher ratings of ease of vividness occurred following PETTLEP imagery compared with traditional imagery, regardless of modality or perspective. Moreover, the vividness of external visual imagery (i.e., imaging from a third-person perspective) was higher after prior observation than traditional imagery. Combining prior observation with PETTLEP imagery may therefore maximize the effectiveness of imagery further. Like LSRT, however, the benefits of different imagery aids on specific imagery processes need further investigation and should be tested with a range of measures.

A practical and straightforward approach, which builds on the method of using a visual demonstration of human action to prime and enhance imagery, is to combine the two procedures *simultaneously*. In terms of the associated neural substrates, motor imagery and action observation involve motor and motor-related brain areas that at least partially overlap, both with one another, and with the regions involved in motor execution (see Hardwick, Caspers, Eickhoff, & Swinnen, 2017). Despite these commonalities, most researchers continue to study imagery and observation effects in isolation from one another (see Vogt, Di Rienzo, Collet, Collins, & Guillot, 2013). More recently, research has instead begun to investigate the effects of motor imagery *during* action observation, with markedly positive and consistent results (e.g., Eaves, Behmer, & Vogt, 2016; Eaves, Haythornthwaite, & Vogt, 2014; Macuga & Frey, 2012; Wright, Williams, & Holmes, 2014).

This instruction typically entails imagining the physiological sensations and kinesthetic experiences of action and synchronizing this motor simulation with the congruent and *concurrently* observed action (Eaves, Riach, Holmes, & Wright, 2016). This procedure seems to be relatively easy for healthy adults to follow and, intuitively, offers a closer representational match to the physical action than simulation through either imagery or observation alone. Performing imagery during observation requires participants to pay close, ongoing visual attention to the observed action, which offers continuous and helpful opportunities for refining and updating the imagined (yet independent) internal representation of the same action in real-time (Eaves, Behmer, et al., 2016; Eaves, Riach, et al., 2016; Scott, Taylor, Chesterton, Vogt, & Eaves, 2017). Such opportunities are, by definition, unavailable when imagery is performed either immediately after or in the absence of a visual primer. There is now a clear opportunity to apply the methods described earlier for LSRT, PETTLEP, and motor imagery during action observation to investigate their effectiveness in developing the specific components of imagery ability discussed in this article. Most likely, this will be a fruitful avenue for future research.

Factors Influencing Imagery Ability

We now turn our attention to factors that might moderate imagery ability and, more specifically, its subcomponents. This endeavor is timely and important, and at present, a remarkably underresearched area. As the studies in this special issue of Imagination, Cognition and Personality demonstrate, research into the factors that influence imagery ability has the potential to yield valuable discoveries, which can inform researchers, theorists, and practitioners alike. The four studies we present here will likely help to develop a series of new and innovative research themes, which future studies can build upon. For the purpose of this introduction, however, it is helpful to first briefly contextualize these studies, by highlighting some of the historical and contemporary discoveries in this field. We will then provide a brief overview of the four articles published in this special issue.

Early attempts to predict task performance based on imagery ability were largely unsuccessful (Hall, Pongrac, & Buckholz, 1985). A major problem in these studies was that the types of imagery tests employed were often inadequate for measuring imagery ability. Accordingly, in the early research, there was a lack of consistent trends between performance outcomes and the available indicators of imagery ability. In an early review, for example, Ernest (1977) concluded that self-reporting using only global statements about imagery ability did not predict performance outcomes.

To address these problems, recent studies have begun to examine the correlations between more specific self-report measures against neurophysiological indicators, leading to more positive results. For example, Shen, Tsai, and Lee (2015) showed participants who report high scores on the Vividness of Visual

Imagery Questionnaire-2 (VVIQ-2) can be disassociated from those with low VVIQ-2 scores, based on recordings of their event-related potentials alone. This measure represents a neurophysiological marker of task-specific cognitive processes, in this case during a metaphor comprehension task.

Runge et al. (2017) recently published a large-scale meta-analysis focusing on imagery vividness, an imagery construct that is closely related to consciousness and prospective episodic memory. They contrasted the efficacy of the two main measures of imagery vividness (trial-by-trial vividness ratings vs. VVIQ scores) for predicting the outcomes in studies using a wide range of behavioral, cognitive, and neurophysiological measures. While trial-by-trial ratings provided significantly larger effect size estimates than the VVIQ scores, both measures were more strongly associated with the neural correlates of imagery, compared with the available cognitive or behavioral measures. For example, in an elegant neuroimaging study, Dijkstra, Bosch, and van Gerven (2017) found the amount of overlap in neural activation (especially in the early primary visual cortex, V1) between (a) imagery and (b) perception was positively correlated with trial-by-trial vividness ratings and imagery ability.

In a related study, Bergmann, Genç, Kohler, Singer, and Pearson (2016) revealed participants with a larger-than-average V1 size experienced more detailed imagery with lower *sensory strength*, whereas individuals with a below-average V1 size showed the opposite pattern. For the majority of their participants with an average-sized V1 region, however, task performance and verbal reports reflected a relative mixture of those two features of visual imagery.

Taken together, these recent landmark studies represent strong progress in imagery ability research. In line with Galton's (1880) perspective, they demonstrate the crucial need to account for individual differences as a moderating factor in any assessment of imagery ability. They also emphasize the need for careful selection of the appropriate task and measurement variables. In this context, an open question remains: Which other factors might influence imagery ability? A potentially useful way to approach this question could be to assess how different factors operate at three core levels of analysis, namely, biological (e.g., genetics and neurophysiology); cognitive (e.g., image generation, inspection, transformation, maintenance); and behavioral (e.g., task performance outcomes). To this end, the first two studies in this special issue used cross-sectional designs to assess the relationship between specific lifestyle factors and imagery ability, which were assessed in terms of cognitive and (in the case of the second study) behavioral indicators. The third study proposes a novel, well-substantiated, and useful behavioral measure of imagery ability, while the final study adopts a longitudinal design to investigate cognitive factors relating to imagery ability over a 13-month period. Next, we give a brief overview of each of the four studies.

In the first study presented here, Shearer, Bruton, Short, and Roderique-Davies (2018) recruited a large sample of athletes from across a wide range of sports. They investigated the relationship between self-reported sleep quality and the ease with which different imagery components can be generated, as assessed via the SIAQ. In recent years, research has established the importance of sleep quality in consolidating both motor learning in healthy participants and motor rehabilitation following brain trauma. Research in other areas of psychology has shown sleep quality also modulates cognitive functions, such as attention, working memory, motivation, and visuomotor performance, and these functions are known to impact imagery ability. Given the vast body of literature that has established both the prevalence and usefulness of imagery in enhancing sports performance, the article reported here by Shearer et al. has far-reaching and practical implications for athletes and their coaches. This is because they show for the first time that sleep quality significantly modulates both global and specific indices of imagery ability, but this effect is not unilateral across the range of imagery components tested.

In the second article of this special issue, Guerrero and Munroe-Chandler (2018) focused on the imagery ability of children between 9 and 11 years of age. Their novel approach was to explore the relationship between the quantity of moderate and vigorous physical activity undertaken (over a typical 7-day period), and the frequency of active play imagery, as well as the ease with which the children could generate movement imagery. With regard to the public health agenda, there are concerns over the widely reported increases in childhood inactivity. While the role of imagery ability has been largely overlooked as a potential mediator in this context, Guerrero and Munroe-Chandler's (2017) article is one of the first to examine this issue.

A child who has good fundamental motor skills (including locomotion, object control, and stability) early on in their life is more likely to play effectively, be more school ready, and later participate in sport and maintain an active lifestyle over a longer duration, facilitating their social inclusion (Merkel, 2013). A well-established finding is that more frequent participation in an activity such as sports is also associated with increases in imagery ability. In the present special issue, Guerrero and Munroe-Chandler's (2017) study reveals that children who engaged more frequently in physical activity also used active play imagery more frequently and that this usage increased with age. This result arguably paves the way for future studies into the role of imagery ability as a potential moderator of health-related behaviors, which might track from early childhood into adolescence and beyond.

In the third study reported here, Boe and Kraeutner (2017) addressed the fundamental question of how to effectively assess imagery ability. In their stimulating review of literature, they outline the core problem facing all research in this area, reminding us that imagery, almost by definition, is extremely difficult to assess in a direct way. While recent neurophysiological studies investigating imagery ability are of course invaluable to the progression of knowledge in this field of research, for athletes and practitioners in sports and exercise, the behavioral level of analysis will remain the ultimate index of success. Self-report measures are inherently limited to the utility of introspection, but they are also often not benchmarked against behavioral outcomes. Boe and Kraeutner have validated a new quantitative and objective assessment tool to address these issues, called *MiScreen*. The tool was developed on the basis of a series of behavioral studies showing sequence learning can be achieved through motor imagery alone, in the absence of physical practice. Using a large sample size, their behavioral paradigm returns a normally distributed data set, which successfully identifies the individual difference gradient in this performance outcome. In their preliminary analyses, however, they found no correlation between the self-report scores on the Kinesthetic and Visual Imagery Questionnaire (Malouin, Richards, Jackson, Lafleur, Durand & Doyon 2007) and the times taken to acquire the sequence learning skill through imagery practice. They argue this may reflect that these two measurements tap fundamentally different aspects of imagery ability that are unrelated in a functional way. Again, this underscores the complex and multidimensional nature of imagery ability, suggesting here that the four imagery processes described earlier in this article may have independent, as well as overlapping properties. Ultimately, this resource will likely be released for wider public use as an application that can be downloaded and installed on smart phones and handheld tablet devices.

In the final article in this special issue, Gregg and Hall (2018) focus on the cognitive level of analysis. They assess the frequency of imagery use, via the Sports Imagery Questionnaire (Hall, Mack, Paivio, & Hausenblas 1998) and imagery ability via the Motivational Imagery Ability Measure for Sports (Gregg & Hall, 2006) over a 13-month period. These measures were quantified in athletes performing predominantly at a national level across different sports. Interestingly, only the cognitive general component of imagery, which relates to pattern recognition, increased in the frequency of use between the start and the end of the testing period. Simultaneously, there was a reduction in motivation general arousal at 5 months into the study. In support of our main proposition in this introduction article, Gregg and Hall's study provides further evidence of the multidimensional nature of imagery ability, in that specific components of imagery use and ability vary independently over the course of the sporting season. Future research can now begin to look in more detail at the kinds of extraneous factors that might drive these changes, such as fatigue, league performance, burnout, sleep quality, and coaching style.

Overall, we are pleased that this special issue brings to the forefront the intractable problem of understanding, defining, measuring, and modifying imagery ability. It is clear a much more nuanced, sophisticated, and detailed appreciation of this complex psychological construct is needed more than ever before. While imagery training programmes have been around for decades now, to achieve greater success in the desired performance outcomes, a more individualized approach appears necessary. Based on the research we present here, modern imagery programmes should account for the potential influence of a whole range of variables that have previously not been experimentally controlled for, such as sleep quality, amount of physical activity, and possible longitudinal changes. Importantly, these influences should be assessed in terms of their impact on the specific and individual components of imagery ability, which relate to task requirements and the appropriateness of the measurement tools available. Ultimately, we hope this special issue helps both academics and practitioners in sports and exercise move away from seeing imagery ability as an undifferentiated general skill but rather view this as a complex and multidimensional construct.

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