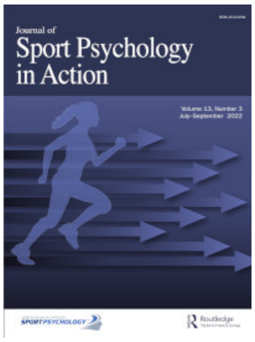

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Recommendations for Combining Action Observation and Motor Imagery Interventions in Sport

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ABSTRACT
Combined action observation and motor imagery (AOMI) interventions involve observing a movement demonstration, usually via video, whilst at the same time imagining the feelings and sensations involved in executing the observed action. Research findings indicate that AOMI interventions can be effective for improving sport performance, yet no guidelines currently exist within the literature to inform applied sport psychologists how to develop and implement AOMI interventions with athletes. The aim of this article is to address this gap in the applied sport psychology literature. Accordingly, the article provides an overview of the 'Science of AOMI' by discussing the neurophysiological, cognitive, psychological and performance effects of AOMI interventions to introduce the concept of AOMI and potential benefits of AOMI interventions in sport. The article then covers the 'Practice of AOMI' by discussing practical recommendations for applied sport psychologists on how to develop and implement AOMI interventions for performance enhancement purposes. Important considerations related to filming the action observation video are discussed, such as selection of the model and choice of visual perspective. Guidelines are then provided for developing and delivering personalized kinesthetic imagery instructions for use by the athlete in synchrony with action observation.

KEYWORDS
AOMI; motor imagery during action observation; dual-action simulation; motor cognition; mental simulation

Action observation (AO) involves watching the movements of either one's self or other people, usually via video or live demonstrations (Neuman & Gray, 2013). Motor imagery (MI) involves imagining the visual and kinesthetic aspects of movement execution (Eaves et al., 2016). It is well-established that both AO (see Ashford et al., 2006; Ste-Marie et al., 2012) and MI (see Cumming & Williams, 2013; Simonsmeier et al., 2020) are effective for improving motor skill performance and learning, particularly when incorporated alongside physical training. As such, applied sport psychologists may use both techniques when working with athletes for performance enhancement purposes.

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Advances in neuroscience have allowed researchers to identify the likely mechanisms through which AO and MI may facilitate improved performance. Using neuroimaging techniques, researchers have compared activity in the brain between experimental conditions involving movement execution, AO and MI. For example, in a meta-analysis comparing over one thousand neuroimaging studies, Hardwick et al. (2018) reported that several brain regions associated with movement execution were activated consistently during both AO and MI, including the bilateral dorsal and ventral premotor cortices and the pre-supplementary motor area. Repeated activation of the motor regions of the brain through either AO or MI may, therefore, contribute to improvements in performance and learning by promoting neural plasticity and adaptation in the brain in a manner similar to physical practice (Holmes & Calmels, 2008).

Despite this overlap in mechanisms underpinning AO and MI processes, the sport psychology literature has tended to consider the two techniques as being separate from each other (e.g., Kim et al., 2017; Neuman & Gray, 2013). Applied sport psychologists may use both techniques in an alternating manner, or use AO to provide a visual representation of the desired movement to prime subsequent MI. Current research, however, indicates that combining AO and MI into a single intervention (i.e., AOMI) may produce enhanced performance outcomes compared to the independent use of either technique (Eaves et al., 2016; Frank et al., 2020; McNeill et al., 2020). The purpose of this article is to introduce applied sport psychologists to the concept of AOMI, make a case for the use of AOMI as a performance enhancement technique for athletes, and outline important considerations relating to the development and delivery of AOMI interventions in applied sport psychology contexts.

Science of AOMI

What is AOMI?

AOMI involves engaging simultaneously in motor imagery *during* action observation (Eaves et al., 2016; Vogt et al., 2013). Approaches in which athletes alternate between AO and MI, or use AO to prime MI, may be beneficial to performance but do not constitute AOMI as described in the recent literature. In AOMI interventions, athletes observe a video of a skill and are instructed to imagine, in synchrony with the observed action, the feelings and sensations that they would experience if they were to execute that movement in an identical manner. As such, visual information regarding movement technique is provided in high definition through the video, allowing the athlete to focus their cognitive and attentional resources toward imagining the kinesthetic sensations associated with movement execution

(Eaves et al., 2016). The imagery component of an AOMI intervention may, therefore, involve imagining the feelings and sensations associated with muscle contractions, joint and limb movements, postural changes, or holding and using relevant implements in synchrony with the action observed on video.

From a practical point of view, AOMI offers numerous benefits compared to the independent use of either technique. For example, not all athletes are initially capable of generating clear and vivid imagery or controlling and maintaining their imagery in the manner instructed by the sport psychologist (Holmes & Calmels, 2008). Furthermore, sport psychologists have no way of knowing with certainty if the athlete is engaging with the MI as instructed, due to the covert nature of the technique. Holmes and Calmels argued that AO videos can overcome many of these issues as the need to generate, maintain, and control a visual representation is removed. However, this can arguably result in a passive intervention that athletes may not find sufficiently engaging or motivating. An AOMI approach may overcome such limitations as the sport psychologist can provide high definition video for the AO component, where they can control all aspects of the visual and auditory stimuli (e.g., technique modeled, viewing perspective and angle, movement speed, and sounds associated with movement execution), whilst the instruction to synchronize kinesthetic imagery alongside the video keeps the athlete engaged actively with the intervention.

Effects of AOMI

Neurophysiological effects

In the past decade, there has been considerable research exploring the effects of AOMI interventions on brain activity. This research has shown consistently that activity in motor regions of the brain is increased during AOMI experimental conditions compared to either independent AO or MI (see Eaves et al., 2016 for a review). For example, using transcranial magnetic stimulation, Wright et al. (2018) compared activity in the motor system during AO, MI, and AOMI of a basketball free throw. The authors reported that activity in the motor system was increased significantly during the AOMI condition, compared to both the AO condition and the control condition. However, in contrast to previous studies (see Loporto et al., 2011), activity in the motor system was not significantly different to the control condition during either independent AO or MI of the free throw. Based on this increased activity in the motor system during AOMI, Wright et al. suggested that AOMI interventions may do more to strengthen the neural pathways involved in movement execution and promote plasticity in the brain than independent AO or MI, and so may prove to be more effective for performance enhancement than either independent AO or MI. However, the direct link between increased neurophysiological activity during AOMI and improved performance following AOMI interventions remains to be established (Frank et al., 2020).

Cognitive effects

Researchers have also considered the effects of AOMI from a cognitive psychology perspective (see Frank et al., 2020). Based on a cognitive approach to motor learning, improvements in an athlete's skill level are underpinned by changes in the mental representations of actions within their skillset (see Schack, 2004 for details on the cognitive action architecture approach). These mental representations comprise cognitive information relating to movement execution, such as required body postures, related movement components, and their associated sensory consequences. When executing a skill, the athlete recalls the relevant mental representation and uses it to guide movement execution (see Frank et al., 2020). Kim et al. (2017) explored the effects of interventions involving either independent AO or MI of golf putting on both the development of mental representations and golf putting performance. They found that both interventions were effective for developing mental representations of putting and improving putting performance in novice golfers. However, the authors suggested that AO and MI may develop the mental representations through different mechanisms. As AO provides visual information depicting movement technique, it may develop aspects of the mental representation related to the sequencing and timing of the different components involved in movement execution. Alternatively, as MI involves generating visual and kinesthetic aspects of movement, it may do more to develop aspects of mental representations related to the sensory consequences of movement execution. Given that AO and MI develop mental representations through different mechanisms, it is possible that combining the two processes in an AOMI intervention may prove to be more effective for developing mental representations of action in the long-term memory, than either independent AO or MI (Frank et al., 2020; Kim et al., 2017; Wright et al., 2018).

Psychological effects

In addition to the neurophysiological and cognitive effects, the improvements in performance and learning associated with independent AO and MI interventions can be attributed partly to psychological processes associated with each technique. For example, AO has been reported to improve self-regulatory processes such as self-efficacy beliefs for specific motor tasks, motivation to engage in practice, self-satisfaction, and reactions to previous performances (Ste-Marie et al., 2012). Similarly, researchers have also demonstrated positive effects of MI on attention, arousal, concentration, motivation, self-efficacy, anxiety, and social processes such as collective efficacy (see Cumming & Williams, 2013).

As AOMI combines these two forms of motor simulation, it is likely that this intervention may benefit such psychological factors to a greater extent. Recently, Shearer et al. (2020) advocated this notion for the manipulation of efficacy beliefs in sport. MI is said to increase efficacy perceptions through the provision of mastery experiences as the athlete draws from previous successful performances to rehearse the task mentally. Using video of a self-model in an AOMI intervention has the potential to enhance mastery experiences further through observing one's self execute an action successfully. Alternatively, if an expert or proficient peer model is used to create the AO video, this provides the athlete with vicarious experiences through the visual display of another athlete performing the task successfully. Shearer et al. proposed that AOMI has the potential to enhance efficacy through the combination of both mastery and vicarious experiences; the two strongest sources of efficacy beliefs (Bandura, 1997). As such, AOMI may have a greater effect on an athlete's efficacy beliefs than independent AO or MI interventions. Further research is required, however, to establish in full the effects of AOMI interventions on a range of psychological characteristics relevant to sport, such as self-efficacy, motivation, and anxiety.

Performance effects

The increased neurophysiological activity reported consistently during AOMI interventions has resulted in various authors advocating AOMI as the current optimal method for delivering mental simulation interventions in sport (e.g., McNeill et al., 2020). This has led to an increase in research exploring the effects of AOMI interventions on motor skill performance. Positive findings have been reported for AOMI interventions across a range of different tasks, including golf putting, balance tasks, and tasks requiring eye-hand coordination (see Eaves et al., 2016; Frank et al., 2020; McNeill et al., 2020 for reviews). For example, Romano-Smith et al. (2018) compared the effect of an AOMI intervention against three other interventions involving (i) alternating AO and MI, (ii) independent AO, and (iii) independent MI for a dart throwing accuracy task. Following an eighteen-session intervention period spanning six weeks, the AOMI intervention was found to produce significant improvements in dart throwing accuracy, relative to both AO and control groups. Similarly, Scott et al. (2018) compared the effect of a three-week AOMI intervention involving Nordic hamstring exercises on peak hamstring force, against both an MI only group and a control group. Relative to the control condition, the AOMI intervention produced a significant improvement in peak hamstring torque, but the independent MI intervention produced no such improvements. Taken together, these findings indicate that AOMI interventions can be effective for improving aspects of motor performance in sport-related tasks. However, further research is required before it can be determined whether AOMI interventions are more effective than independent AO or MI, and how this may vary across different tasks and skill classifications (McNeill et al., 2020).

Practice of AOMI

Application of existing guidelines

As independent AO and MI are established techniques, applied sport psychologists can draw on existing best practice guidelines related to each technique (e.g., Cumming & Williams, 2013; Holmes & Collins, 2001; Law et al., 2018; Ste-Marie et al., 2012) to inform the development and delivery of AOMI interventions. For example, the PETTLEP model (Holmes & Collins, 2001) outlines seven factors related to MI (Physical, Environment, Task, Timing, Learning, Emotion, Perspective) that sport psychologists should consider when developing imagery interventions with athletes. The incorporation of PETTLEP principles within imagery interventions has been shown to be beneficial to sport performance (e.g., Smith et al., 2007), and so should be factored into the design of AOMI interventions. To achieve this, and to aid kinesthetic imagery alongside action observation, athletes may find it helpful to complete their AOMI whilst holding relevant sport-specific implements, wearing their sport-specific clothing, and adopting the appropriate stance (Physical), and where possible do this in the competition or training arena (Environment). The video component should be presented in real-time, and the imagery should be instructed in synchrony with the real-time video (Timing). The video content in the AOMI intervention should be updated as the athlete's skill level progresses (Learning), and both the video content and imagery instructions should promote emotional experiences similar to those experienced when competing (Emotion). Finally, the visual perspective from which the video is recorded should be informed by the nature of the skill for which the intervention is being developed (Task, Perspective). Further details on applying PETTLEP imagery can be found in Wakefield and Smith (2012).

The following sections discuss key issues related to the development of AOMI interventions that should be considered alongside existing guidelines such as PETTLEP. Figure 1 provides a visual representation for applied sport psychologists of the processes involved in developing and delivering

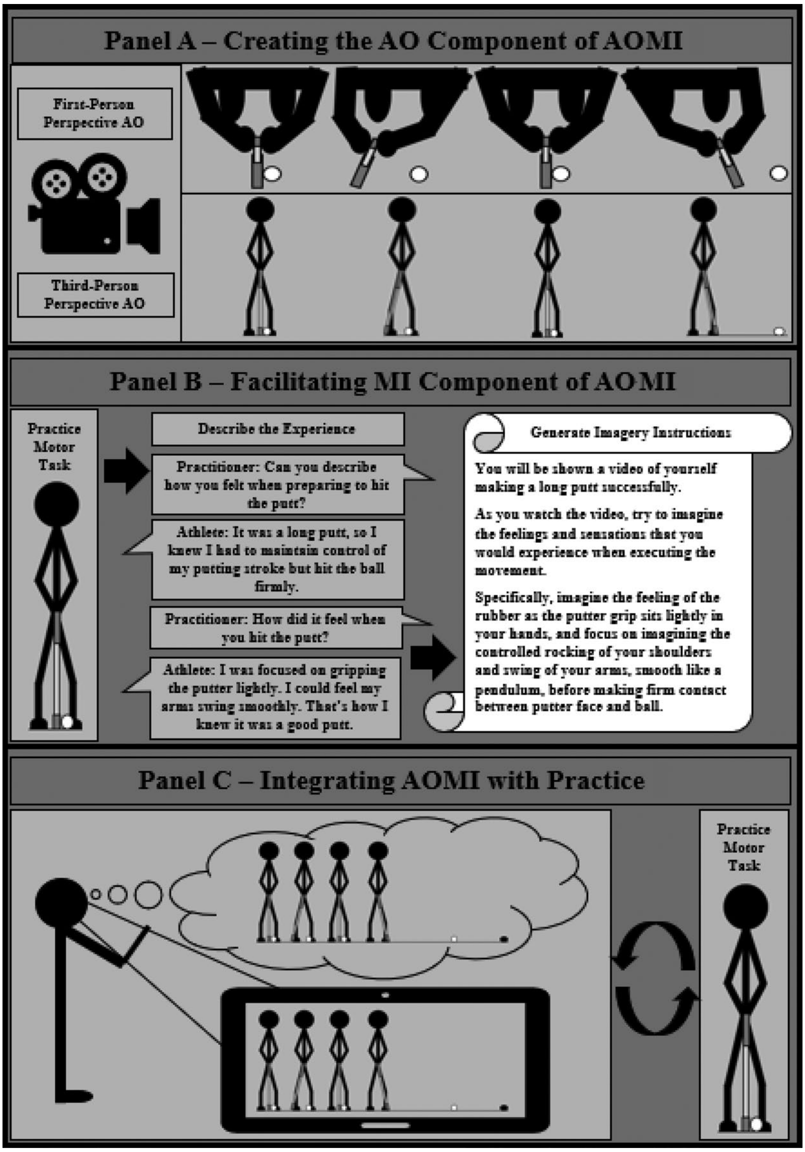

Figure 1. Guidelines for integrating AOMI interventions with physical practice using a golf putt as an example motor skill. *NB*: The information presented in Panel B is provided as an example of how the applied sport psychologists should personalize the imagery instructions based on the athlete's responses, it should not be interpreted as the only instructions to provide for this skill.

an AOMI intervention and is intended to supplement the information discussed in the following sections.

Creating the action observation component

Technological advances have resulted in high quality video recording equipment being readily available in the form of compact digital video cameras, tablet devices, mobile phones, and body-mounted cameras (Law et al., 2018). In the following sections, key considerations for the creation of appropriate video content for use in an AOMI intervention are outlined, although the athlete's preferences should always be considered in conjunction with these recommendations to ensure that the intervention is personalized and meaningful to the athlete (Cumming & Williams, 2013; Holmes & Collins, 2001).

Selecting a model

Observing a model who demonstrates performance errors can have skill learning benefits in some cases (see Ste-Marie et al., 2012), but it is preferable for AOMI interventions that the model exhibits proficient performance. This is important as the athlete synchronizes imagery of how it would feel to execute the observed movement alongside the AO content, and reinforcement of inaccurate or error-strewn movements through MI can be detrimental to performance (Cumming & Williams, 2013).

When selecting the type of skilled model to use, applied sport psychologists have several options (see Law et al., 2018; Ste-Marie et al., 2012). Whilst the majority of AOMI research to date has used a skilled other as the model for the AO component, applied sport psychologists may find self-modelling AOMI interventions to be particularly effective when supporting athletes for performance enhancement. Self-modelling AO interventions are created by recording the athlete's own successful movement execution and are known to be effective for enhancing both performance and self-efficacy beliefs (Law et al., 2018; Ste-Marie et al., 2012). A self-modelling approach for AOMI interventions may serve to personalize the AO component and add meaning to the synchronous MI component; factors that are highly recommended for MI interventions (Cumming & Williams, 2013; Holmes & Collins, 2001). For example, self-related visual and auditory information depicting the athlete's own limbs, clothing, and equipment, as well as their unique pre-performance routines, movement patterns, and breathing patterns, may facilitate MI of the feelings and sensations associated with movement execution. Where forms of self-modelling AO may not be possible, for example when an athlete is injured or when supporting novice athletes who are unable to execute the movement successfully, use of an expert or proficient peer model may offer an acceptable substitute.

Choice of visual perspective

Given the wide-range of video recording technology available commercially, applied sport psychologists can capture high quality content for use in AOMI interventions with ease (Law et al., 2018). Head- or body-mounted cameras allow video creation from the athlete's own viewpoint (first-person visual perspective), whilst tripod- or gantry-mounted cameras allow the recording of third-person visual perspectives from various different positions (see Figure 1, Panel A). Although increased neurophysiological activity and enhanced performance effects have been shown following AOMI recorded from both perspectives (see Eaves et al., 2016), applied sport psychologists should consider the type of skill when determining the optimal visual perspective for the AOMI intervention.

A first-person visual perspective may facilitate kinesthetic imagery by providing a viewpoint that closely matches movement execution (Holmes & Collins, 2001), but this perspective often fails to capture visual information regarding movement technique. As such, for skills where various techniques can be used to achieve success (e.g., passing a soccer ball), a first-person visual perspective may be most appropriate to aid strong kinesthetic imagery alongside the observed stimuli. Conversely, third-person visual perspectives can convey visual information regarding movement technique more easily, despite providing a viewpoint that is less closely matched with movement execution and so makes kinesthetic imagery more difficult (Holmes & Calmels, 2008). As such, for skills where use of a specific technique is required for successful performance (e.g., a gymnastics routine), third-person visual perspectives may be preferable as they provide a visual representation of the desired technique with which the athlete can synchronize their kinesthetic imagery. Self-modelling may be particularly useful with third-person visual perspectives as kinesthetic imagery may not be possible from this perspective when the agent is another person (Holmes & Calmels, 2008).

Instructing the motor imagery component

As mentioned, AOMI involves engaging in MI *during* AO. As high definition visual stimuli can be provided through the AO video, there is no requirement for the athlete to generate visual imagery of movement execution. Instead, the athlete should focus primarily on engaging in kinesthetic imagery by imagining how it would *feel* to execute the movements that they observe on screen. Important considerations related to the imagery component of an AOMI intervention are now discussed.

Personalizing the motor imagery

A key principle in current MI guidelines is that imagery should be personalized to the individual athlete (Cumming & Williams, 2013; Holmes & Collins, 2001; Williams et al., 2013). This recommendation extends to AOMI interventions. As discussed, the AO component can be personalized by using self-modelling to promote a sense of agency and considering the athlete's visual perspective preferences. Further personalization can be achieved through the MI component. Imagery instructions developed solely by the sport psychologist and prescribed to the athlete are not recommended. Instead, the athlete and sport psychologist should develop the imagery instructions together, with the athlete taking an active role in selecting the imagery content and terminology used (Williams et al., 2013). This can be achieved by applying response training (Lang et al., 1980), whereby the athlete describes their experiences when imagining the skill and their responses are incorporated into the imagery instructions. To facilitate kinesthetic imagery in an AOMI intervention, applied sport psychologists may find it helpful to ask the athlete to imagine and recall the specific kinesthetic sensations or emotional responses that they experienced during the imagery (i.e., the response and meaning propositions of the image; see Lang et al., 1980), such as a "burning" in their muscles or "smoothness" in their technique, and incorporate these descriptions, using the same language used by the athlete, within the imagery instructions (see Figure 1, Panel B). This ensures that imagery instructions provided to the athlete are personally relevant and meaningful, and so should facilitate more vivid kinesthetic imagery during the intervention.

Emphasizing kinesthetic imagery instructions

It is common to provide athletes with written or audio imagery scripts during MI interventions (see Williams et al., 2013). These are often detailed, describing what the athlete should imagine in a step-by-step manner. Arguably, this detail could reinforce the cognitive control of movement in a manner characteristic of novice performance. However, in AOMI interventions, the video provides the athlete with the visual information that they would normally have to generate, control, and maintain for themselves. As such, the detail in the imagery instructions can be reduced considerably, and the emphasis can be placed on instructing the athlete to generate kinesthetic imagery (Eaves et al., 2016).

To guide kinesthetic imagery in synchrony with the observed video, a three-step instructional process is recommended (see Figure 2). First, the sport psychologist should provide the athlete with a brief description of the visual stimuli that will be shown in the video (Figure 2, Step 1). Second, they should instruct the athlete to imagine, in synchrony with the video, the physiological feelings and sensations that they experience when executing the observed movement (Figure 2, Step 2). Third, the sport psychologist should personalize the imagery instructions, whilst also reinforcing kinesthetic imagery, by emphasizing the sensations and emotional responses that the athlete self-reported during response training (Figure 2, Step 3).

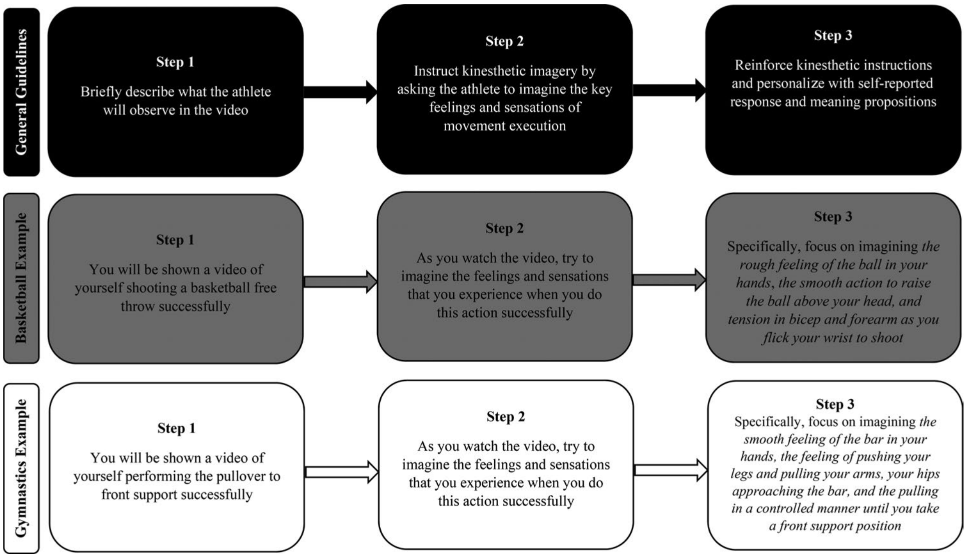

Figure 2. Guidelines for emphasizing kinesthetic imagery instructions for use in AOMI interventions. *Italics* indicate examples of how the instructions should be personalized by including the athlete's own kinesthetic imagery descriptions.

Future research directions

To advance the field further, future sport psychology research should seek to verify the efficacy of AOMI interventions in different sports, and across different skill types and expertise levels, to establish in which situations AOMI interventions might be most effective. Further empirical investigation manipulating the effects of different AOMI intervention design considerations (e.g., model type, visual perspective, and personalization) would also be beneficial. In addition, as virtual reality technology becomes more accessible to applied sport psychologists, exploration of the efficacy of delivering AOMI interventions through virtual reality would also be worthwhile.

Conclusion

In recent years, there has been an increased research and theoretical focus on AOMI interventions (see Eaves et al., 2016; Frank et al., 2020; McNeill et al., 2020). Research findings demonstrating the efficacy of AOMI for performance enhancement have been reported in the literature (e.g., Romano-Smith et al., 2018; Scott et al., 2018; see McNeill et al., 2020 for a review). However, until now, practical information for applied sport psychologists detailing how to develop and deliver AOMI interventions was absent. This article addressed that gap by providing a research-informed rationale for the use of AOMI interventions in sport, together with advice regarding important considerations related to their design and development. Applied sport psychologists are encouraged to use the information provided in this article to develop and implement effective AOMI interventions to enhance sport performance.

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