Experimental Brain Research
https://doi.org/10.1007/s00221-021-06126-4

REVIEW

Looking beyond the binary: an extended paradigm for focus of attention in human motor performance

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Received: 29 September 2020 / Accepted: 27 April 2021

Abstract

Focus of attention (FOA) has been shown to affect human motor performance. Research into FOA has mainly posited it as either external or internal to-the-body (EFOA and IFOA, respectively). However, this binary paradigm overlooks the dynamic interactions among the individual, the task, and the environment, which are core to many disciplines, including dance. This paper reviews the comparative effects of EFOA and IFOA on human motor performance. Next, it identifies challenges within this EFOA–IFOA binary paradigm at the conceptual, definitional, and functional levels, which could lead to misinterpretation of research findings thus impeding current understanding of FOA. Building on these challenges and in effort to expand the current paradigm into a non-binary one, it offers an additional FOA category—dynamic interactive FOA—which highlights the dynamic interactions existing between EFOA and IFOA. Mental imagery is then proposed as a suitable approach for separately studying the different FOA subtypes. Lastly, clinical and research applications of a dynamic interactive FOA perspective for a wide range of domains, from motor rehabilitation to sports and dance performance enhancement, are discussed.

Keywords Focus of attention · Motor performance · Mental imagery · Dynamic neuro-cognitive imagery · Dance

Focus of attention: an overview of current literature

Execution of motor tasks requires levels of attention. Defined as a cognitive system (Posner and Petersen 1990), attention has been referred to as "the active process of perceiving and extracting information from ongoing events in a selective, active and economical manner" (Gibson and Rader 1979). The limited, selective resources associated with attention are allocated either purposefully or involuntarily and are involved in determining which information will gain access to working memory (Schmidt 2014; Knudsen 2007). Attention is also referred to as a concentrated mental activity, which is divisible, shiftable, and sustainable (Schmidt 2014; Krasnow and Wilmerding 2015). Specifically, the ability to identify, direct, and sustain one's attention on information—either real or imaginary—relevant to task accomplishment is called focus of attention (FOA; aka attentional focus). Directing attentional resources during movement execution (Schmidt 2014; Fazekas and Nanay 2017; Yao et al. 2013) requires a conscious "decision-making" process (Coull and Nobre 1998) based on perceptual information (Kosslyn et al. 2001). FOA impacts motor performance (Wulf 2013; Wulf and Lewthwaite 2016; Singer 2000; Vidal et al. 2018) through, among others, affecting movement kinematics (Lohse et al. 2010; Munzert et al. 2014; Zentgraf Karen 2009), kinetics (Lohse and Sherwood 2012), and pain (Damme et al. 2010) as well as recalibrating the perceptual system (Harbourne and Stergiou 2009). As FOA is inherent to motor, cognitive, sensory, aesthetic, and psychological components, including mind–body awareness (Krasnow and Wilmerding 2015) of performance, it applies to a wide

Communicated by Patrick Haggard.

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Published online: 16 May 2021

variety of domains ranging from sports (Porter et al. 2010) to rehabilitation (Van Damme et al. 2010; Hunt et al. 2017). Moreover, FOA is particularly utilized in somatic modalities and form-based disciplines, such as dance (Cicchella Antonio 2015; May et al. 2011). Therefore, examples from dance are included throughout the paper to support the ideas discussed in it.

Research into the effect of FOA on motor performance has included a wide variety of motor tasks, from fine motor skills (e.g., pressing piano keys (Robert et al. 2011) to gross ones (e.g., marathon running) (Stevinson and Biddle 1998) and in a variety of populations and levels of expertise. The beneficial effects of FOA have been studied within the contexts of motor learning, performance enhancement, and rehabilitation. Typically divided into a binary of "external" or "internal" FOA with discrete boundaries (Wulf 2013; Wulf and Lewthwaite 2016; Brodie and Lobel 2012; Wulf and Su 2007; Wulf 2007), most research has studied their comparative effectiveness on motor performance. The relative merits of using external or internal FOA have been assessed with a variety of methods, including retrospective verbal verification through self-reports (Guss-West and Wulf 2016; Teixeira da Silva et al. 2017) and interviews (MacPherson et al. 2008), biomechanics, functional performance, and brain imaging (Kuhn et al. 2017; Scheibner et al. 2017).

External FOA (EFOA) refers to focusing on the intended movement's effect or outcome and/or the environment (i.e., anything that is outside one's body (Brodie and Lobel 2012), including implements (Wulf and Su 2007; Wulf 2007; Guss-West and Wulf 2016). Subcategories of EFOA (i.e., close versus distant) have been suggested based on the distance of the FOA from the individual's body (McNevin et al. 2003). Studies considering the benefits of EFOA have included focusing on the pendulum-like motion of a golf club (Wulf and Su 2007), the forward pushing of a pedal during a cycling-like task (Totsika and Wulf 2003), a swimmer pushing the water back with the arms (Stoate and Wulf 2011), and a dancer focusing on marks on a wall (aka spotting), elements on stage, or other dancers (Cicchella Antonio 2015). Among the suggested neuro-physiological mechanisms of effect associated with EFOA are facilitation of a more efficient recruitment of motor units and reduced co-contractions of agonist and antagonist muscles (Lohse et al. 2011) and greater economy in movement production (e.g., reduced EMG activity) (Vance et al. 2004). Furthermore, according to the "constrained action hypothesis (Wulf et al. 2001) ", EFOA has been suggested to utilize more automatic control processes (Abdollahipour et al. 2015). EFOA has also been found to speed up motor learning processes (Land et al. 2014; Wulf and Prinz 2001) and reduce attentional demands (Guss-West and Wulf 2016; McNevin et al. 2003; Wulf et al. 2001; Wulf and Prinz 2001). However, identifying and focusing on something external to the body during performance of certain skills, such as those in dance and gymnastics, can be challenging (Becker et al. 2018). Furthermore, while EFOA may distract individuals from signs of bodily discomfort (Morgan and Pollock 1977) sensed with an internal focus, the inability to notice how the body is doing in a general sense can be a disadvantage in somatic modalities and form-based disciplines such as dance, which require body awareness (Brodie and Lobel 2012; Guss-West and Wulf 2016) and attention to information from bodily sensations, feelings, and experiences (Green 2002; Enghauser 2007). To that point, an alternative to EFOA—holistic FOA (i.e., focusing on a general feeling of a movement)—has been suggested, especially when EFOA is not practical or desired (Becker et al. 2018).

Internal FOA (IFOA; sometimes linked to "association strategy" (Morgan and Pollock 1977) or "skill-focused" (Beilock et al. 2002)) refers to directing attention toward one's body (Van Damme et al. 2010), including its parts (Wulf 2013; Brodie and Lobel 2012; Oliveira et al. 2013) and tissues, movements (Wulf and Su 2007; Guss-West and Wulf 2016; Totsika and Wulf 2003), physiology (e.g., breathing, muscular activity, heart beat) (Schucker et al. 2014; Connolly and Janelle 2003; Masters and Ogles 1998), and bodily information and sensations (e.g., temperature, effort, tension, pain) (Damme et al. 2010; Morgan and Pollock 1977; Schucker et al. 2014; Masters and Ogles 1998; Franklin 2012, 2014a, b). Subcategories of IFOA have been suggested (Morgan and Pollock 1977; Schucker et al. 2014; Franklin 2005) to include automated internal processes (e.g., breathing, heart rate) (Western and Patrick 1988; Schucker and Parrington 2018), body parts, or physical sensations (Schucker et al. 2014); therefore, interoception (i.e., one's awareness of inner bodily signals and information) (Hill et al. 2017) can also serve as IFOA. IFOA is typically associated with cognitively breaking down the motor task into its components (Beilock et al. 2002; Beilock and Carr 2001) to provide relevant kinesthetic and perceptual cues (Guss-West and Wulf 2016; Beilock et al. 2002), thereby potentially placing cognitive and attentional demands on the performer (Couvillion and Fairbrother 2018). IFOA is associated with the default (intuitive and automatic) network of brain activation (Buckner et al. 2008) and addresses both automated and non-automated processes (Hill et al. 2017) which can then contribute to activating self-regulating mechanisms (Brick et al. 2015). IFOA has been suggested to assist optimal motor performance through achieving constant improvement (Hill et al. 2017) and new levels of excellence (Toner and Moran 2015) as well as re-organizing movement patterns in contexts emphasizing movement form (Guss-West and Wulf 2016; Peh et al. 2011). According to the "constrained action hypothesis", IFOA interrupts automatic organizing components of the motor system during the performance of a task, which can lead to in return, to deterioration of performance

(Becker et al. 2018; Schucker et al. 2014). Also, as IFOA increases muscular co-contraction, efficiency in force production can be reduced (Lohse and Sherwood 2012).

Factors associated with the individual, the task, and the environment all interact with each other to affect FOA (Chua et al. 2018). Examples for such factors include the performer's level of expertise, learning strategy and FOA preferences (Weiss et al. 2008; Maurer and Munzert 2013), perceptions and previous experiences, self-awareness, psychological state (Bernier et al. 2011), and body representations (e.g., body schema, body structural description, and body image) (Schwoebel and Coslett 2005; Radell et al. 2004, 2011; Holmes and Spence 2004). As for the performer's skill level, a predominant theme in the FOA literature suggests that performers at all skill levels could benefit from EFOA to a greater extent, compared to IFOA (Wulf 2013; Wulf and Su 2007; Bell and Hardy 2009), with IFOA even hampering performance in experts (Wulf 2013; Wulf and Su 2007) and enhancing task complexity in novices (Zentgraf Karen 2009). However, this view is contradicted by other literature suggesting that novices may not be hampered by IFOA (Ford et al. 2005) and even incur a greater benefit from it compared to EFOA (Beilock et al. 2002; Peh et al. 2011; Perkins-Ceccato et al. 2003). Moreover, some studies found that expert performers did not exhibit relative gains in performance between EFOA and IFOA conditions (Wulf 2008; Winkelman et al. 2017).

Factors associated with the task itself, including its characteristics (e.g., speed, duration) and goals (Guss-West and Wulf 2016; Bernier et al. 2011), also play a role in directing FOA. Specifically, performance under pressure situations that induced anxiety (aka "choking under pressure" (Hardy et al. 1996)) has been suggested to promote focusing internally (Beilock and Carr 2001; Bernier et al. 2011; Baumeister 1984). Instructions and feedback, which are important players in motor learning and performance (Krasnow and Wilmerding 2015; Schmidt and Lee 2014; Poolton and Zachry 2007), also direct FOA (Munzert et al. 2014; Becker et al. 2018; Hill et al. 2017; Chua et al. 2018). Certain components (e.g., content, wording, and delivery method) of the instructions highlight or emphasize specific elements within the task and thus——either explicitly or implicitly——engage one's FOA (Wulf 2013; Hackney 2001). Such instructions and feedback could inadvertently result in an FOA which differs from the originally intended one (Becker et al. 2018; Peh et al. 2011). For example, instructing dancers to focus on an "X" marked on the wall (a common strategy in dance known as "spotting") while performing a pirouette (a single leg pivot turn) (Chua et al. 2018) could serve as an EFOA, thus distracting them from focusing internally on movement form. Related to this, 84.6% of athletes competing at the USA Track and Field Outdoor National Championships reported their coaches provided them with instructions that promoted IFOA (Porter et al. 2010). Providing no FOA-related instructions, however, has been previously referred to as a "self-selected/preferred FOA" condition (Chua et al. 2018). A study involving basketball players found that participants' self-preferred and familiar FOA was found to yield the best performance in a free throw task, regardless of whether being IFOA or EFOA (Maurer and Munzert 2013). Interestingly, some performers tend to intuitively choose IFOA when they are not instructed otherwise (Porter et al. 2010; Land et al. 2013; Pascua et al. 2015), as demonstrated in a survey reporting that 69.2% of USA Track and Field athletes reported using self-selected IFOA (Porter et al. 2010). Self-selected FOA in dance is, however, equally inconclusive. While self-selected FOA was associated with a better pirouette performance in experienced female dancers (Cicchella Antonio 2015), other studies demonstrated that self-selected FOA corresponded with the FOA that yielded optimal quantitative performance only in 30.77% (for postural sway) and 53.85% (for balance duration) of participants. Furthermore, the self-selected FOA corresponded with the FOA that yielded the best qualitative performance (i.e., form) only in 38.46% of participants (Chua et al. 2018). Self-surveys of 53 professional ballet dancers found them to use either IFOA (63.1%), a combination of both (36.1%), or EFOA (27.7%) during the performance of selected ballet movements (Guss-West and Wulf 2016). Another study of 13 skilled dancers found that 84.6% of participants used multiple (i.e., 2–5) foci during performance, with 53.8% of participants using both EFOA and IFOA, 30.7% using EFOA, and 15.3% using IFOA (Chua et al. 2018). However, for the cases of combined FOA, no further details were provided in regards to the manner in which these two foci were used (e.g., simultaneously, sequentially, etc.).

Current literature lacks consensus regarding which type of FOA, if any, has a superior effect on motor performance (Krasnow and Wilmerding 2015; Peh et al. 2011; Lawrence et al. 2011; Castaneda and Gray 2007; Andrade et al. 2020), and is more automatic and efficient (Wulf et al. 2001; Buckner et al. 2008; Kal et al. 2013). Many reports point to a superior beneficial effect of EFOA over IFOA, finding it relatively robust in a variety of tasks (Schucker and Parrington 2018) and aspects of performance (Marchant et al. 2009, 2011; Ducharme et al. 2016; Wulf et al. 1998) and for various populations (Wulf 2013; Wulf and Prinz 2001), regardless of age or level of expertise (Wulf 2013; Guss-West and Wulf 2016). Furthermore, this superior effect has been shown to be relatively permanent and long term (Wulf et al. 2003). Conflicting evidence asserts, however, that this effect is short-lived in specific populations, such as typically developing children (Krajenbrink et al. 2018). On the contrary, other research finds that EFOA not only fails to demonstrate a superior effect in highly trained acrobats (Wulf 2008), novices (Lawrence et al. 2011), and older adults (Yogev-Seligmann et al. 2017), but also that IFOA has a superior effect on muscular activity during a dart throwing task in novice players (Marchant et al. 2009), in rowing performance in female collegiate rowers (Connolly and Janelle 2003), on running performance in recreational runners (LaCaille et al. 2004), and in novice baseball and golf learners (Peh et al. 2011; Perkins-Ceccato et al. 2003; Castaneda and Gray 2007).

Which FOA type is more beneficial for dance performance is also questionable. While some studies point to the aesthetic (Cicchella Antonio 2015) and physiological (Nigmatullina et al. 2015) advantages associated with EFOA in dance, other literature did not find a superior beneficial effect associated with EFOA in comparison to IFOA (Chua et al. 2018; Denardi and Corrêa 2013). For example, a study involving 72 college students with no previous experience in classical ballet did not find a statistically significant difference in learning (both acquisition and retention) and performing a pirouette among external, internal, or generalized (i.e., no specific IFOA instruction) FOA (Denardi and Corrêa 2013). Similarly, another study on pirouette performance of 13 skilled dancers did not find a statistically significant effect for either IFOA, EFOA, or no-focus instructions on postural sway, balance duration, and movement form (Chua et al. 2018). Furthermore, for each of these three performance indicators, the FOA that yielded the best performance varied among participants (Chua et al. 2018).

A preponderance of studies tried to identify a consistent preference for EFOA versus IFOA in motor performance. The inconsistent trend of superior effect of either FOA strategy might be attributed to the wide variety of motor tasks, populations, and assessment methods used across studies. Furthermore, such inconclusive research findings imply an effect of FOA that is task-specific and participant-related (Stevinson and Biddle 1998; Guss-West and Wulf 2016; Schucker et al. 2014), rather than an absolute effectiveness of one focus over the other. For example, a study investigating the effect of EFOA versus IFOA on number of jumps and errors in 15 novice and 15 expert jump ropers found that each group was affected differently from four different foci conditions (i.e., EFOA and IFOA targeting either upper or lower body) (Couvillion and Fairbrother 2018).

Furthermore, building on literature and research findings from fields of cognitive neuroscience, motor learning, and embodied cognition, looking from an "either or" approach may fail to elucidate FOA reality (and thus its effectiveness). Therefore, motor performance FOA studies would do well to include variables within and among the individual, the task, and the environment (Chua et al. 2018). Therefore, an analytical appraisal that re-considers FOA concepts based on identified challenges within the current paradigm could provide novel insights into FOA and its effectiveness for motor performance.

Challenges within a binary view of FOA

The current EFOA–IFOA binary paradigm poses challenges (Teixeira da Silva et al. 2017; Lohse et al. 2011; Western and Patrick 1988) at the conceptual, definitional, neuro-cognitive, and functional levels, detailed below.

Conceptual level How one perceives their environment (and their body in relation to it) is largely based on context, thoughts, and emotions (Krasnow and Wilmerding 2015). In addition, the boundaries between external- and internal-to-the-body are often non-discrete (Canzoneri et al. 2013) (Fig. 1; see also 'Neuro-Cognitive Level' below). For example, perceiving an EFOA as either "farther" or "closer" (McNevin et al. 2003) is largely determined by one's somatosensory and spatial perception (i.e., perceiving the distance of the focus from one's body as being "far" or "near").

Definitional level Currently used conceptualizations and operational definitions of FOA vary among studies and are not always clear or standardized (Hill et al. 2017; Bell and Hardy 2009). For instance, separating body movements, traditionally defined as IFOA (Wulf and Prinz 2001), from their effects, traditionally defined as EFOA (Wulf and Prinz 2001), often requires an artificial distinction, such as differentiating the pushing of the foot (i.e., body movement) from the pushed pedal (i.e., effect).

Neuro-cognitive level The discrete boundaries between "external-to-the-body" and "internal-to-the-body"—and hence EFOA and IFOA—are mutable (Canzoneri et al. 2013) (Fig. 1), potentially involving somatosensory and sensorimotor processes (Maravita et al. 2002). Mutable boundaries between external- and internal-to-the-body involve body schema (i.e., the mental representation of the body and its parts in relation to each other) (Tsay et al. 2015; Senkowski and Heinz 2016). Body schema, associated with IFOA, could be altered by, among others, physical [e.g., low

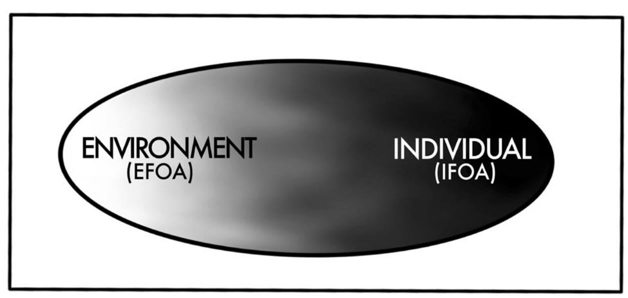


Fig. 1 Non-discrete boundaries: the non-discrete boundaries between the environment and the individual as also reflected in external and internal FOA

back pain (Moseley 2008)], sensory (e.g., pain Tsay et al. 2015; Senkowski and Heinz 2016), or neurological–cognitive (e.g., Parkinson's disease Cohen et al. 2011; Abraham et al. 2019a, b) conditions, possibly due to distorted afferent sensory information from specific body parts and/or their processing. Neuroimaging studies in primates found that a handheld rake (i.e., a tool)─traditionally defined as EFOA─was recognized by the brain as an extension of the hand (Maravita and Iriki 2004), and thus most likely interpreted as IFOA (Fig. 2).

Similarly, a focus on one's internal body parts, such as hands, can be considered as EFOA when they become objectified (i.e., perceived as an object external to the body) (Iriki 2006). Furthermore, a focus on a prosthesis can be perceived as either "bodily extension" or "body incorporation" (De Preester and Tsakiris 2009), the former focusing on the prosthesis as a detached, external tool and the latter as an integrated part of one's body (De Preester and Tsakiris 2009). These two approaches to the same focus would be perceived differently, as EFOA and IFOA, respectively. In dance, aligning with neuroscience literature (Cardinali et al. 2009), props such as capes or scarves might at first be perceived by the dancer as EFOA, but over time, they might come to incorporate the prop as part of their body and as such, perceive it as IFOA.

Functional level Motor skills in context involve attending to environmental components and constraints (e.g., objects, other individuals, and space) (Krasnow and Wilmerding 2015). For example, reaching for an object involves considering the object's nature, location, and size as well as one's hand trajectory and its distance from the object. For such tasks, attending to only one FOA—either external or internal—fails to capture the full context of the motor task and may affect intrinsic and extrinsic feedback, thus degrading performance (Riccio 1993). Rather, motor tasks are likely to require attending to both foci in an integrated manner: for example, attending both to one's fingers (IFOA) and the rungs (EFOA) in a jump-and-reach task (Wulf et al. 2007), focusing on both the foot (IFOA) and the pedal (EFOA) in a cycling task (Totsika and Wulf 2003); feeling both one's body (IFOA) and the water through which it is moving (EFOA) in a swimming task (Stoate and Wulf 2011); or focusing on both foot alignment (IFOA) and the floor (EFOA) while landing from a jump (Coker et al. 2015). Doing so allows for focusing one's attention on the interactions among the individual, the task, and the environment during motor task execution thus promoting better management of large amounts of information from both within and beyond the body (Cicchella Antonio 2015; Bartenieff and Lewis 1980; Brodie and Lobel 2012) as well as potentially promoting improved motor planning, execution, and control.

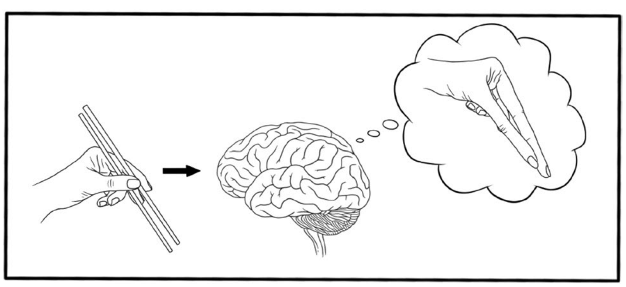


Fig. 2 Mutable perceptional boundaries of the body: an external-to-the-body object (i.e., EFOA) can be recognized by the brain and interpreted as internal-to-the-body (i.e., IFOA) (adapted from Maravita et al. 2002, 2004)

Research into a non-binary view of FOA that acknowledges the non-discrete and mutable boundaries between EFOA and IFOA is warranted (Becker et al. 2018; Bernier et al. 2011) and will likely require the inclusion of ways in which dynamic interactions among individual, environmental, and task-specific factors are translated into FOA.

Applying dynamic interactions to FOA

Because FOA is a cognitive process, it is shaped by ongoing changes in information coming from one's body, the task, the environment, as well as the dynamic interactions existing between them (Wilson 2002; Morasso et al. 2015), and thus contributes to a non-binary perspective. Furthermore, dynamic interactions among external and internal sources play a role in driving and controlling motor behavior (Iriki 2006; Morasso et al. 2015; Maringelli et al. 2001) and are foundational in numerous fields, including sensorimotor integration (Rasman et al. 2018), cognitive psychology (embodied cognition) (Wilson 2002; Morasso et al. 2015), ecological psychology (dynamic systems) (Gibson 1986; Davids et al. 2008), and motor learning (Newell 1991). This basic concept is also expressed in Newton's third Law of Motion (aka "The Law of Action-Reaction") asserting that when one body exerts a force on a second body, the second body responds by exerting a reaction force on the first body that is equal in magnitude and opposite in direction. Therefore, focusing on the point of contact would include, for example, the dynamic mutual forces (i.e., pressure) exerted by one's foot and the floor in gait (Chua et al. 2018), or by one's foot and the pedal in cycling (Totsika and Wulf 2003). Another kind of interaction involves that of a dancer's body with their kinesphere (Laban 1974). Interactions between foci of attention, either physical or sensory (e.g., visuo-spatial (Maringelli et al. 2001)), contribute to efficient motor planning, execution, and control (Krasnow and Wilmerding 2015; Davids et al. 2008; Newell 1991). To attend to different stimuli, one can focus attention either sequentially (Oliveira et al. 2013), by switching back and forth between foci (Bernier et al. 2011), or by attending to the foci simultaneously (but unrelatedly) (Stevinson and Biddle 1998; Guss-West and Wulf 2016; Hardy and Callow 1999). For example, skilled performers may very well shift their attention between different internal and external foci to promote continuous improvement (Toner and Moran 2014; Shusterman 2008) and correction of errors (Fitts 1967; Beilock et al. 2004). Referring to dynamic interactions within FOA (herein referred to as Dynamic Interactive FOA; DIFOA) allows for perceiving the different foci as a single, unified system while acknowledging each individual focus along with relationships and feedback loops, and even non-discrete boundaries in some cases, existing among them (Fig. 3). Doing so, DIFOA goes beyond focusing on multiple foci simultaneously, but as separate entities (often referred to as 'combined EFOA–IFOA') (Guss-West and Wulf 2016). For example, while practicing tossing and catching a ball in rhythmic gymnastics, the gymnast engages in DIFOA by focusing on the constantly changing distance between the ball and their hand throughout the task.

Using DIFOA bundles the foci of attention associated with the individual, task, and environment, thereby offering an encompassed way to maintain a consistent focus which could reduce attentional load and interference with conscious processes, as suggested by the "constrained action hypothesis" (Wulf et al. 2001). One way to support such a bundling foci of attention within the context of motor performance is through cognitive techniques such as mental imagery, including analogies (i.e., a single, all-encompassing metaphor) (Masters 2000; Komar et al. 2014).

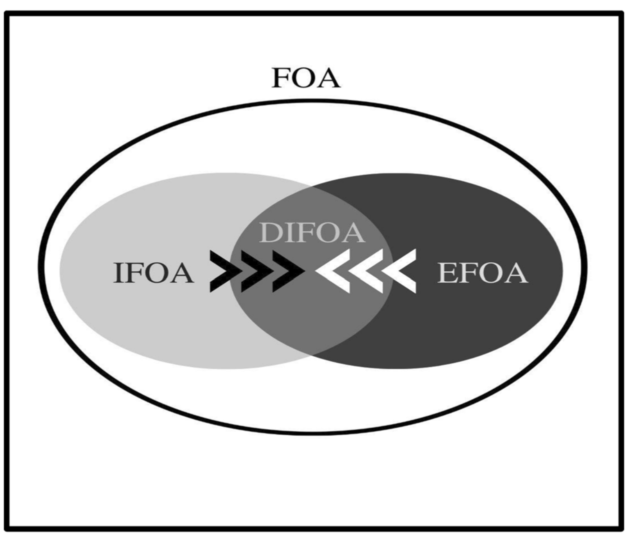


Fig. 3 Dynamic interactive focus of attention (DIFOA): DIFOA as a single, unified system which acknowledges both foci as well as the non-discrete boundaries and dynamic interactions existing between them

The unique nature of DIFOA makes it potentially more suitable and effective, at least in some cases, than EFOA or IFOA alone or even compared to combined EFOA–IFOA. Such an enhanced effect of DIFOA could especially be realized in motor tasks and scenarios that are highly dependent upon interactions between the individual and the environment, such as in rhythmic gymnastics and dance. Potential differentiating predictions for DIFOA include enhanced efficiency, accuracy, and consistency, as well as heightened motivation, engagement, and enjoyment in movement. Among the fundamental challenges within this emerging field is finding ways (e.g., cueing and feedback strategies) to assure a clear differentiation between combined EFOA–IFOA and DIFOA. Doing so along with addressing the above denoted challenges in current literature, future research should explore the possible added value of DIOFA by conducting basic (e.g., neuro-cognitive mechanisms pertaining to DIFOA) and applied (e.g., performance outcomes) research. Specifically, there is a need for randomized controlled trials that compare EFOA, IFOA, combined EFOA–IFOA, and DIFOA.

Applying mental imagery to focus of attention

Experiences serving as FOA are triggered by either real or imaginary sensory inputs using perception or mental imagery (MI), respectively (Golomer et al. 2008). MI is the cognitive process of creating any experience (e.g., visual, auditory, kinesthetic, olfactory, etc.) in the mind (Kosslyn et al. 1993, 2001; Moran 2009; Dickstein and Deutsch 2007) with or without movement execution. MI and FOA both involve cognitive (Coull and Nobre 1998) and perceptual processes (Kosslyn et al. 2001) mutually linked (Fazekas and Nanay 2017; Caliari 2008; Fournier et al. 2008; Calmels et al. 2004) to direct one's attention. Furthermore, sharing similar neuro-cognitive circuits with perception (Dijkstra et al. 2017, 2019), MI has been shown as capable of modulating it (Fazekas and Nanay 2017; Andrade et al. 2020). For example, the frontal cortex has been implied in selective attention during both perception and MI (Nobre et al. 2004; Ishai et al. 2002).

MI is dependent upon attentional resources (Yao et al. 2013; Pearson 2007), including by recruiting cognitive attentional strategies (Fazekas and Nanay 2017; Abraham et al. 2018, 2019b, c). For example, focusing on pain (Van Damme et al. 2010) might impede one's ability to mentally image a smooth, full-range movement. In line with this, in a study investigating the effect of MI and MI combined with action observation (AO) training on hamstring eccentric force, a beneficial effect was detected in the right leg only following MI + AO ($p < 0.01$) and approached significance following

MI ($p < 0.1$) (Scott et al. 2018). Given the training's contents addressed both legs, the authors suggested that spontaneously (i.e., with no instructions) attending to the dominant (right) leg could explain such a lateralized effect (Scott et al. 2018).

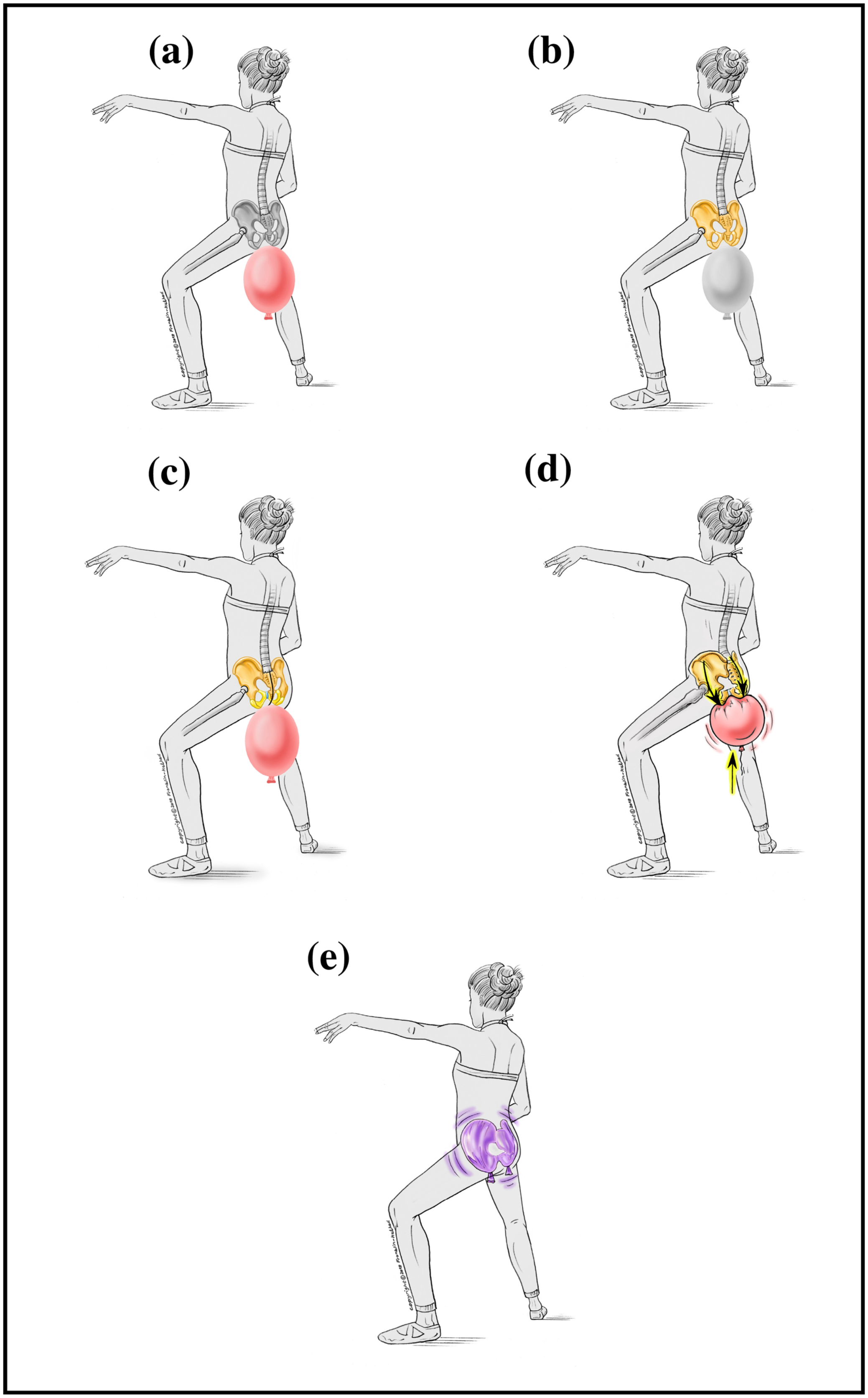
Inversely, MI is often employed by FOA (Calmels et al. 2004; Cumming et al. 2007; Cumming and Ramsey 2009) and can direct, and even manipulate (Andrade et al. 2020) FOA via sensory and perceptual processes (Fazekas and Nanay 2017; Dickstein and Deutsch 2007). Insofar as MI controls various FOA-related variables (e.g., perspective, content, etc.), it presents as a suitable tool for FOA. MI's use in driving FOA is thought to be context- and goal-specific (Bernier et al. 2011; Fournier et al. 2008). Specifically, MI can enhance one's engagement with FOA through offering additional FOA-related information and through increasing concentration (Andrade et al. 2020; Murphy et al. 2008). Support for the MI's effect on FOA can be found in a study showing that 20.06% out of 688 expert golfers used imaginary FOA (Bernier et al. 2011). An example for MI's precise effect is kinesthetic MI, consisting of imaging one's own bodily sensations (Abraham et al. 2019; Jeannerod 1994), which is more likely to facilitate IFOA or DIOFA. Engaging in kinesthetic MI elicited greater somatic arousal (i.e., less occipital alpha activity) than did engaging in visual MI (Davidson and Schwartz 1977).

MI is suggested to develop an implicit understanding of different features of a motor task (Driskell et al. 1994; Callow et al. 2013), thus serving as an EFOA (Wulf and Prinz 2001; Beilock et al. 2002) or IFOA (Peh et al. 2011) that might not have been available otherwise. This may be particularly advantageous when the selected focus is not perceptually available (e.g., due to vision or hearing loss) but can be accessed via MI. For example, focusing on (and mentally imaging) a favorite scenery in nature without being there. Factors associated with MI, such as MI ability (Abraham et al. 2019), perspective taking (i.e., internal first person, external first person, or third person; employed by the use of mirrors, mental imagery, etc.) (Kahalon et al. 2018) have been considered to impact FOA. Of note, the MI terminology of "internal" and "external" (Yao et al. 2013) often refers to the MI perspective [i.e., "internal" for first person and "external" for third person (Yao et al. 2013)] rather than to the attentional foci associated with it. Therefore, internal and external MI are not always congruent with IFOA and EFOA, respectively.

The MI contents can be either realistic or imaginary and take different forms, such as images, metaphors, and analogies (Fazekas and Nanay 2017; Guss-West and Wulf 2016; Abraham et al. 2019; Wulf et al. 1999; Lotze and Halsband 2006), MI's beneficial effects have been demonstrated in a wide range of domains and populations (Abraham et al. 2016, 2017, 2018, 2019b; Coker et al. 2015; Dickstein and Deutsch 2007; Cumming and Ramsey 2009; Cumming and Williams 2009; Pavlik and Nordin-Bates 2016; Abrahamson and Bakker 2016; Giron et al. 2012), including for improving both attention (Calmels et al. 2004; Cumming and Williams 2009) and dance performance (Coker et al. 2015; Abraham et al. 2016, 2017, 2019c; Pavlik and Nordin-Bates 2016; Abrahamson and Bakker 2016; Giron et al. 2012). As a cueing and FOA strategy, MI is core to movement practices and dance and is used for enhancing various aspects of motor performance (Guss-West and Wulf 2016; Franklin 2012, 2014a; Pavlik and Nordin-Bates 2016; Sweigard 1974; Krasnow and Deveau 2010; Krasnow 1997). For example, about 28% of self-reported FOA used by professional dancers consisted of images (Guss-West and Wulf 2016). MI's richness in contents, modalities, and perspectives alongside its ability to include both realistic and non-realistic contents alike, makes it highly suitable for incorporating dynamic interactions between various foci of attention and serve as a cueing method. For example, mentally imaging the dynamic interaction between one's expanding lungs and their surrounding pleura during inhalation (internal DIFOA) or the dynamic interaction between one's knee while squatting and its imaginary surrounding filled with honey (internal–external DIFOA).

One MI approach that systematically considers the dynamic and interactional relationships among a person, task, and environment relevant to FOA is dynamic neurocognitive imagery (DNI; also known as the "Franklin Method") (Franklin 2012, 2014a; Abraham et al. 2019; Heiland and Rovetti 2013; Heiland et al. 2012). DNI is a codified MI-based movement and postural retraining method that utilizes different MI types (e.g., anatomical, biomechanical, metaphorical, etc.), modalities (e.g., visual, kinesthetic, auditory, etc.), and perspectives (e.g., first- and third-person perspectives) with the goal of enhancing motor and non-motor functioning. As DNI offers a wide variety of MI tools and content (Franklin 2012, 2014a), specific DNI images on which to focus can be tailored for use in motor contexts with different individuals, tasks, and environments. For example, a study used DNI images for shoulder–hip relationship were used to study interaction between artistic motor abilities and MI during preparation for a pirouette in international ballet dancers and age-matched untrained females (Golomer et al. 2008). DNI's codification and versatility enables it to distinctly target the different FOA types (e.g., internal, external, both, and interactive).

DNI's ability to distinctly address the various FOA subtypes is demonstrated by the following depiction: the image of a helium balloon underneath the pelvis (Fig. 4) is used in dance to facilitate smoothness better pelvic alignment of a plié (i.e., a dance movement consisting of bending and straightening the knees) with the imaged balloon supporting (lowering and rising) the pelvis. However, there


(a)
(b)
(c)
(d)
(e)

◂**Fig. 4** Dynamic neuro-cognitive imagery for addressing FOA: the use of dynamic neuro-cognitive imagery (DNI) to distinctly target different FOA in a dancer performing a plié for facilitating smoothness and better pelvic alignment. The dancer can focus on the imaged helium balloon (EFOA; **a**), their pelvis (IFOA; **b**), both the balloon and pelvis as two separate entities (combined IFOA–EFOA; **c**), the dynamic interaction between the balloon and the pelvis (DIFOA; **d**), or the metaphor of the pelvis as a balloon (**e**) (drawn by Eric Franklin, all rights reserved)

are multiple options in attaining its technical and artistic goals. The dancer could focus on either the imaged balloon (EFOA; Fig. 4a), the pelvis (IFOA; Fig. 4b), or both the pelvis and the imaged balloon as two separate entities (combined IFOA–EFOA; Fig. 4c). The dancer could also focus on the dynamic interaction between the pelvis and the imaged balloon, thus fully capturing its sensory components such as touch, pressure, support, and motion. (DIFOA; Fig. 4d). In addition, the dancer could use metaphorical DNI by focusing on the pelvis *as* a balloon (Fig. 4e). This DNI metaphor in the form of an analogy merges the characteristics and qualities of both entities (i.e., the actual pelvis and the imaged balloon). This singular–yet holistic–metaphor may be more easily perceived and remembered by dancers as well as better communicated by teachers and choreographers (Pavlik and Nordin-Bates 2016; Hanrahan and Salmela 1990). However, the question of whether, and if so how, such analogies dissolve the dynamic interaction between its components remains to be answered.

Along with its seeming suitability, MI poses a few challenges when used within FOA. First, the MI process is not always an intuitive one, especially for those with no previous experience with MI or with low MI ability (Abraham et al. 2017, 2019a, b, c). Second the cognitive load associated with MI when used as a FOA strategy–compared to non-MI FOA strategies–is not fully known and requires furthers investigation.

Summary

This paper reviews FOA literature within the context of human motor performance toward identifying challenges and limitations in the current binary FOA paradigm. Applying the non-discrete boundaries between external- and internal-to-the-body as well as to the dynamic interactions existing between the body, the task, and the environment is suggested. Subsequently, an additional FOA category–DIFOA–is proposed. Furthermore, MI, and specifically DNI, are suggested as suitable and promising tools for comprehensively, yet sensitively, using and researching FOA including its mechanisms of effect. It is thought that this extended FOA paradigm has applications for a variety of contexts, from motor learning and control to rehabilitation, sports and dance performance and training. Furthermore, exploring FOA using MI holds promise for advancing FOA knowledge and supporting the shifting view of FOA from a binary to an interactive, non-binary one.

Acknowledgements The authors would like to thank Eric Franklin (Fig. 4), Madison Christian (Figs. 1 and 2), and Audrey Enghauser (Fig. 3) for their contribution to this paper.

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