**There are two sides to the focus of attention coin in motor learning: evaluating information processing and ecological dynamics perspectives**

**Learning and Skill Acquisition in Sports: Theoretical Perspectives**

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**Abstract**

Allocating our focus of attention to pertinent locations when planning and executing movements can benefit outcome performance, cognitive efficiency, and physiological efficiency. For instance, individuals may benefit from adopting an external focus of attention (i.e., by focusing attention on the effects of one’s movements on the environment) over an internal focus of attention (e.g., focusing on one’s body movements). However, accounts concerning the theoretical functioning of such effects have primarily relied on hierarchical information processing perspectives; far less consideration has been given to potentially alternative explanations based on ecological dynamics and the applied implications thereof. Within the present review, we: (a) outline the most recent developments in attentional focus research; (b) evaluate similarities and differences between information processing and ecological dynamics explanations of the focus of attention effect; (c) provide practical recommendations; and (d) discuss future research avenues. In doing so, a case is made for an ‘Ecological Dynamics Account of Attentional Focus’ to act as an alternative to information processing-based hypotheses.

**Keywords:** *attentional focus; sport; movement; skill; cognition; dynamical systems*

**The Attentional Focus Phenomenon and its Far-Reaching Application**

Verbal instruction is one of the most common methods of conveying information to individuals when learning and performing motor skills. However, it is now well established that the language we use when providing instruction can influence the skill acquisition process, particularly in relation to whether it directs an individual’s attention internally (i.e., towards the body) or externally e.g., towards the effect of one’s movements on the environment (1 Wulf, 2013), or towards external perceptual information from the physical properties of the world around us (specifying information; 2 Gibson, 1979). This is consistent with early rhetoric from James (3 1890) when discussing the influence of attention on movement outcomes: “Keep your eye at the place aimed at, and your hand will fetch the target; think of your hand, and you will likely miss your aim” (p520). There is now a wealth of literature supporting an external focus of attention for several performance outcomes, including accuracy, speed, cardiovascular endurance, maximum force production, movement kinematics and motor economy (for reviews see 4 Neumann et al., 2019; 1 Wulf, 2013). Benefits of an external focus extend beyond sport and have also been applied to enhance movement solutions within the military (5 Amini & Vaezmousavi, 2020) and medical fields, e.g., when working with Parkinson’s (6 Wulf et al., 2009), stroke (7 Aloraini et al., 2020), or multiple sclerosis patients (8 Shafizadeh et al., 2013) as well as those with intellectual disabilities (9 Chiviacowsky et al., 2013); in older populations (10 Chiviacowsky et al., 2010) and falls prevention (11 Rhea et al., 2019); or within rehabilitation environments such as recovering from ankle sprains (12 Laufer et al., 2007) or ACL reconstructive surgery (13 Ghaderi et al., 2021).

**Recent Research Directions**

*The Interactive Effects of Focus Distance and Task Relevance*

When selecting appropriate external foci, some contexts require practitioners to decide between multiple alternatives. For example, a hockey coach directing attention towards the club versus the ball, or a medical doctor attending to their scalpel versus the target epidermis. This conundrum has led researchers to investigate ‘the distance effect’, whereby benefits of distal over proximal foci were first identified by McNevin et al. (14 2003), on the basis that attending to movement effects further from the body are more easily differentiated from the body and thus more likely to facilitate automaticity. However, more recently Singh and Wulf (15 2020) have shown that whilst this is certainly the case for experts, novice performance is likely superior when adopting a more proximal focus, more closely aligned with technique. Here, differential findings as a function of expertise were also supported with measures of focus preference (i.e., experts preferred a distal focus and novices more proximal). Singh et al. (16 2022) have accounted for these findings with the notion of functional variability when distality of focus is appropriately matched to expertise level. Specifically, the authors showed evidence for enhanced coordination of the shoulder, elbow and wrist in a volleyball serve, for skilled performers adopting a more distal as opposed to proximal focus.

However, it is possible that focus relevance may moderate the relationship between expertise and focus distance (17 Herrebroden, 2023). Amini and Vaezmousavi (5 2020) reveal enhanced shooting performance in elite military personnel when adopting more task relevant external focus (regardless of distality) (see also 18 Russell et al., 2014). However, it could be argued that the secondary focus points in these studies were more aligned with dual-task approaches as opposed to true ‘movement effects’, thus accounting for inferior performance in those instances.

 Recent research has thus, emphasized the complexities of selecting appropriate external foci for learning and performance. Mechanistic explanations underpinning the attentional focus phenomenon have tended to emphasize the role of an external focus to augment congruence between planning and action, and ultimately enhance automaticity of motor programming (see Prinz’s, (19 1997) common coding principle and Wulf et al.’s, (20 2001) constrained action hypothesis, respectively). However, it stands to reason that these mechanisms rely on there being a more tangible (i.e., relevant) movement effect such as motion of a club, racket, or ball (21 Lawrence et al., 2011). In the absence of this, Lawrence et al. (21 2011) argue that the benefits of an external focus may be diminished. Whilst there remain some inconsistencies in the literature when investigating this type of task (see also 22 Abdollahipour et al., 2015), there is little doubt that from a practitioner perspective, some tasks may exhibit challenges when identifying more salient movement effects e.g., within floor gymnastics or dance. More recently, Becker et al. (23 2018) present a novel solution to such instances, via a holistic attentional focus that is targeted towards generalised feelings of the movement to inhibit conscious control of effectors. When tested in a standing long jump, findings revealed that both an external and holistic focus enhanced performance, with no statistical difference between the two. Becker and colleagues advocate a holistic focus when an external focus is neither practical nor desired. A similar solution which adopts what the authors term a ‘mind over body’ approach, entails replacing body parts (in this instance, the supine forearms in a volleyball pass), with the depicted image of an external object (in this case a ‘platform’) (24 Singh & Wulf, 2022). This shows promising findings and is consistent with more traditional implicit learning techniques such as analogy learning (25 Liao & Masters, 2001).

Interestingly, the distance effect has also been considered in the context of an internal focus. Pelleck and Passmore (26 2017) have identified more severe undesirable consequences of adopting an internal focus when it is more closely associated with a skill reliant on environmental afferent information. In a golf putt, measures of movement accuracy, muscle activity, and kinematics were all adversely affected when directing attention towards upper-body as opposed to lower-body limb mechanics. This suggests that the disturbances to the motor system when focusing internally, may be concentrated towards more skill-relevant bodily factors in tasks otherwise reliant on environmental information. It is conceivable that focusing on skill-relevant internal body-based information may actually be of least relevance to far-aiming tasks such as golf, since the motor system is capable of self-organising without a need for conscious monitoring (see also 27 Parr et al., 2023).

*Inter-related Variables*

Irrespective of nuances surrounding the distance effect and skill relevance, the literature to date presents a robust representation of the attentional focus phenomenon, and benefits of an external focus. However, this literature has typically considered the relationship between small numbers of variables in isolation, for example the influence of an external focus of attention on electromyography (EMG) or movement amplitude, somewhat removed from the greater ecological context (see 1 Wulf, 2013 for a review). These linear methodologies have justifiably been adopted in the name of conserving methodological integrity and rigour. However, more recent research direction has begun to embrace more holistic and non-linear methodologies, arguably more consistent with skill acquisition in practice. For example, it is rare that a single variable such as focus of attention will act in isolation on performance and so it is important that we consider the interactive effects of inter-related variables. In this manner, Wulf and Lewthwaite’s (28 2016; 29 2021) OPTIMAL theory (optimising performance through intrinsic motivation and attention for learning), proposed that learning is a consequence of interactions between both attentional and motivational factors. The authors speculate that the ideal sensorimotor and motivational conditions can lead to enhanced goal-action coupling via more efficient functional connections across brain networks, and increased performance expectations e.g., self-efficacy, sense of competence, and agency. These circumstances can be achieved through external focus instructions combined with conditions of autonomy support.

*Ecological Validity*

 This shift in research direction to investigate the attentional focus phenomenon more holistically, has also cemented a need to test this in more ecologically valid environments. Despite an extensive literature-base supporting the robustness of an external focus of attention to enhance a breadth of movement outcomes (see 1 Wulf, 2013), the field has arguably failed to bridge the gulf between theory and practice. There remain significant discrepancies between what is advocated by empirical research and the language being observed from coaches and practitioners in the field (30 Winkelman, 2021). Research methodologies embracing the value of investigating attentional focus in more ‘naturalised’ environments, are likely to give us a better understanding of the ‘what, when, why, and how’ of different focus instructions and strategies, and subsequently identify why these discrepancies exist so that we might ensure efficacy of coach education. Whilst several studies have now adopted observational approaches to identify the nature of attentional focus instructions and strategies employed in sport and rehabilitation environments (e.g., 31 Keller et al., 2022; 32 Lee et al., 2022; 33 Porter et al., 2010; 34 Powell et al., 2021), richer qualitative approaches (e.g., 35 Orr et al., 2021) have advanced this further to: a) explore the functionality of different focus instructions across both practice and competition environments; b) investigate differences in attentional focus across different aspects of the game i.e., the short versus long game; and c) identify the mechanisms influencing adoption of attentional foci, e.g., self-generated versus coach-led instruction. Findings highlight the complexities underpinning the attentional focus phenomenon and might account for discrepancies between research and practice. For example, whilst coaches had a role in influencing the attentional focus adopted in elite-level golf, there was a lack of consistency between the attentional focus advocated by coaches and what was adopted by players in practice and competition (35 Orr et al., 2021). Furthermore, the attentional focus adopted by players varied between the short- and long-game (with players more likely to focus on the body during the short-game) and focus during competition environments was typically self-generated by players as opposed to coming from the coach. Isolated coach education interventions are therefore unlikely to be sufficient in enhancing the extent to which an external focus is employed during practice environments.

 This raises the question as to whether there remain some further complexities that warrant addressing prior to an external focus of attention being fully embraced as a coaching ‘tool’. This line of thinking is consistent with arguments made by Collins et al. (35 2016), that question the rigidity of proposed implications to coaching practice made by Abdollahipour et al. (22 2015). More specifically, Collins and colleagues emphasize some caveats of making suppositions on the back of attentional focus instructions that are a) tested in lab environments and lacking representation to applied practice; and b) not developed by the individuals using them and thus detached from familiarity and preference. This further accentuates the need for this phenomenon to be tested more rigorously in naturalised environments.

 When investigated in more ecologically valid settings with athletes, Anderson et al.’s (37 2022) findings are consistent with the notion that the attentional focus effect is likely more complex than is currently portrayed by the literature. The authors adopted machine learning techniques to identify patterns of attributes that differentiated between two groups of athletes: high and low performing Olympic weightlifters. Odds ratio analyses revealed that athletes were 9.5 times more likely to achieve high-performing status if they had completed over 281 hrs of practice using an internal focus of attention by the first phase of testing. It is important to note however, that whilst this was the case, athletes were also 9.3 times more likely to reach the same status if they had completed over 346 hrs using an external focus of attention by the same stage. Together, these findings suggest that different types of focus instructions might possess different functions during an athlete’s development.

*Facilitative Somaesthetic Awareness*

 Similarly, Toner and Moran (38 2015) propose a functional ‘somaesthetic awareness’ for correcting bad habits. They advocate switching between what they term more reflective (internal) and unreflective (external) modes of bodily awareness, the same way in which an athlete might switch between the autonomous and associative phases of learning (39 Fitts & Posner, 1967) when making adjustments to problematic movements that would normally be executed outside of conscious control. This is also consistent with Carson and Collins’ (40 2011; 41 2014; 42 2016) non-linear Five-A model of technical refinement (analysis, awareness, adjustment, (re)automation, and assurance), wherein the process of skill refinement is differentiated from that of skill learning. The second stage of the process centres around ‘awareness’ with the authors arguing that the skill must be ‘de-automised’ prior to technical corrections being made. More recently, Gottwald et al. (43 2020) suggest that an internal focus (or somaesthetic awareness) may also have value when congruent with afferent information more useful for task success e.g., proprioceptive tasks such as artistic gymnastics. This was tested over a series of three studies using upper and lower limb extension tasks, where pertinence of proprioceptive information was enhanced by removing vision or adding weighted objects to limbs involved in movement production. Enhanced movement economy via reduced EMG activity was consistent with outcome measures of performance accuracy when adopting a congruent internal focus. These findings warrant further investigation in more ecologically valid tasks but may account for the incongruous findings in Olympic weightlifting (37 Anderson et al., 2022), where proprioception is arguably integral to successful movement execution of the snatch and clean and jerk. In a similar task, Kal et al. (44 2015) also revealed trends supporting enhanced automaticity for stroke patients when adopting an internal focus. The authors accounted for these findings with the notion that this population may have had a preference for using an internal focus in daily life, perhaps strengthened by familiarity as inferred from Collins et al. (45 2016).

This notion of a facilitative somaesthetic awareness is also supported by Moore et al. (46 2019), who investigate the value of using different attentional focus prompts in rearfoot-striking runners, to correct problems in their gait and achieve a flatter foot at ground contact. An internal focus was shown to be more effective for retraining kinematics with no detriment to physiological responses. Similarly, Schücker et al. (47 2014) showed that focusing on the feeling of the body in endurance running did not disrupt movement economy if the focus was not directed towards a highly automated process such as breathing. This has implications for use of an internal focus for pacing. Similarly, Neumann et al. (48 2020) have revealed benefits of an internal focus in rowing where performance outputs were not constrained. Participants focusing on a series of internal versus external cues, showed performance benefits via distance rowed, power output per stroke and physical exertion. These complexities suggest that internal and external foci might be more appropriate for different functional roles. Recent evidence (49 Aiken et al., 2022; 50 Becker et al., 2020) suggests that switching attention between movement preparation and execution might benefit performance. This is also supported by Gottwald et al. (43 2020) who identified benefits of an internal focus for motor planning, but not control, in proprioceptive tasks.

**Focus of Attention from an Information Processing Perspective**

Accounts concerning the theoretical functioning of the attentional focus effect have arguably been skewed towards hierarchical information processing (IP) perspectives, wherein movement plans are purportedly stored in memory and transmitted to the limbs for execution (51 Newell, 1991). Cognitive, or ‘IP’ accounts of motor learning, adopt the standpoint that the brain is a metaphoric ‘computer’, processing sensory inputs prior to providing an output in the manner of an appropriate motor response (52 Broadbent, 1958). This theoretical perspective relies heavily on schema theory (53 Schmidt, 1975; 54 2003), which proposes that the general characteristics of actions (i.e., relative timing and force) are represented cognitively in memory and can be drawn upon for fast motor execution when required. Different states of memory, or ‘schemas’ have responsibility for different processes, with the recall schema responsible for movement production and the recognition schema responsible for movement evaluation, allowing for error detection and correction. Whilst some features of Schmidt’s original (53 1975) motor schema theory have been contradicted empirically in the literature (see 54 Schmidt, 2003), the primary tenet of IP accounts of motor learning, which still stand today, supports the notion that actions are ‘pre-programmed’, a direct contradiction to mechanisms underpinning ecological dynamics frameworks.

Wulf et al.’s seminal (55 1998) series of studies, which were arguably the impetus for the attentional focus research, first accounted for the benefits of an external focus in a ski-simulator and balance task, with ideomotor-based principles of motor learning (see 56 Greenwald, 1970). Whilst traditional IP models present a certain dissociation between perception and action (i.e., input and output), ideomotor principles propose that actions are indeed represented in the brain but in relation to their anticipatory sensory consequences. Prinz’s (19 1997) common-coding theory proposes a shared coding system for perception and action. In line with this, Prinz’s action-effect principle suggests that “actions are planned and controlled in terms of their effects” (p. 152). Wulf et al. suggested that providing (external) instructions that direct attention towards the effects of one’s movements on the environment, only serves to augment the intrinsic association between afferent and efferent information and enhance skill learning. If actions are ’coded’ in line with their movement effects, then it stands to reason that adopting an internal focus of attention will likely inhibit automaticity of response programming.

Wulf and colleagues (20 Wulf et al., 2001) tested this hypothesis in a balance task, where participants had to respond to an auditory tone by pressing a button as fast as possible whilst balancing under either internal or external focus conditions. As hypothesised, an external focus of attention facilitated automaticity of the motor system, evidenced by faster probe reaction times combined with enhanced balance performance. These findings led to the conception of what is now well established in the literature as the ‘constrained action hypothesis’. Specifically, Wulf et al. (20 2001) proposed that an internal focus directs conscious attention to otherwise automatic movement processes, that operate more efficiently and effectively if left unattended via an external focus. These mechanisms have since been supported rigorously with various neurophysiological and kinematic measures, including electromyography (EMG), electroencephalography (EEG), and movement variability (57 see Gray, 2011). More specifically, reductions in muscular activity via EMG support the notion of increased movement economy when using an external focus (58 Vance et al., 2004) and this effect has now been replicated in dynamic tasks such as jumping (59 Wulf et al., 2010) or shooting in basketball (60 Zachry et al., 2005), as well as more static tasks where EMG data is arguably more stable e.g., within isometric force production (61 Lohse et al., 2011). Parr et al. (27 2023) extended this by testing EMG, together with EEG during an isometric upper limb force precision task to better understand neuromuscular control as a function of attentional focus. Findings were consistent with previous literature, with the forearm flexor showing greater EMG activity when using an internal focus but also increased EEG alpha activity across the parieto-occipital cortex, a possible indication of increased conscious processing. Support for enhanced cortical processing has also been corroborated with measures of movement planning. Data suggests that an external focus may facilitate offline planning efficiency via reduced pre-movement times in an isometric force production task (62 Lohse, 2012). This is further evidence for increased automaticity and reduced conscious processing. Furthermore, and not surprisingly, these neurophysiological benefits seem to result in more optimal movement kinematics. For example, Lohse et al. (63 2010) showed evidence for increased variability (standard deviation) at the shoulder joint upon extension, when adopting an external focus of attention in a darts throw. This ‘functional variability’ is consistent with Bernstein’s (64 1967) degrees of freedom problem, which proposes that movements are only constrained to the point where functionality is optimised.

Wulf and Lewthwaite (28 2016; 29 2021) have since tried to consider these attentional mechanisms in conjunction with psychological factors underpinning motor learning, on the basis that the role of motor, social, cognitive, and affective mechanisms should be considered as complex interactions in line with human function, and not in isolation. Specifically, OPTIMAL theory (optimizing performance through intrinsic motivation and attention for learning), proposes that adopting an external focus of attention in conjunction with enhanced expectancies for success, stimulates advantageous dopamine responses, augmenting ‘goal-action coupling’. This is based on the notion that learners working in these sensorimotor and motivational environments will become more focused on their task goals and direct focus away from the self. Wulf and Lewthwaite speculate that this can result in a continuous cycle of enhanced motor learning, whereby an external focus of attention combined with enhanced expectancies for success results in not only successful movement outcomes, but also increased levels of self-efficacy and positive affect, which in turn influence perceived competence and so the cycle continues. However, early empirical tests of OPTIMAL theory, provide equivocal support for this framework (e.g., 65 Sertic et al., 2021; 66 Simpson et al., 2020; 67 2021). Simpson and colleagues (2020) revealed that although an external focus, led to enhanced motivational states (i.e., self-efficacy, perceived competence, task effort, and positive affect), integrating attentional focus with conditions that enhanced expectancies for success did not provide additional motor-performance benefits over and above an external focus alone, in a standing long-jump task. Further research testing the complex interactions between attentional and psychological mechanisms is warranted.

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**The Ecological Dynamics Account of Attentional Focus**

 The ecological dynamics approach to motor learning posits that, instead of movement plans being stored in memory and called upon when needed, movement is instantaneously organised without reliance on memory, based on the dynamical interaction between the organism, task, and environment (68 Gibson & Gibson, 1955; 69 Gibson & Pick, 2000; 70 Kelso, 1995; 71 Davids, Button, & Bennett, 2008). Individuals’ direct perception of the situational opportunities for action (i.e., affordances) in relation to their organismic, environmental, and task constraints, enables them to dynamically self-organise movement coordination into stable states (i.e., attractors) which achieve the desired goal. Consequently, an ecological dynamics framework features greater explanatory power than information processing accounts, with regards to individuals’ functional adaptability within a world high in degrees of freedom (72 Araujo et al. 2006; 71 Davids et al., 2008). For example, even in the most exceptional of circumstances when playing soccer (e.g., opposition players obstructing the field of vision, heavy rain, wind, uneven pitch terrain, and temporarily reduced range of movement as a result of injury), players can still exhibit capacity for successful passes. For both novelty and storage reasons, information processing-based mechanisms are less able to account for such instances than ecological dynamics. Given the explanatory power of ecological dynamics and its growing prominence within motor learning (73 Button et al., 2020), it is timely to develop an ‘Ecological Dynamics Account of Attentional Focus’.

Firstly, Prinz’s (19 1997) action-effect principle of common coding suggests that movements should be planned in relation to their intended effects for optimal parameter selection; a mechanism which Wulf et al. (55 1998) propose is facilitated by an external focus of attention on intended movement effects, such as a target (see 74 Roberts & Lawrence, 2019). However, the presently proposed Ecological Dynamics Account of Attentional Focus offers an alternative explanation for common coding, in the form of direct perception. This concept proposes that individuals do not perceive the world in terms of absolute physical parameters (e.g., speed and angle of a player) and instead in terms of affordances (e.g., whether the player can be tackled; 75 Gibson, 2003; 76 Dotov et al., 2012). Essentially, the environment is directly perceived in proportion to the organism’s intentions and motor capacities. Within this framework of perception, cognition plays the role of a supervisor (77 Araujo, 2009; 78 Davids et al., 2015) and distributes resources for the perception of task-relevant (specifying) information across the body and environment. Consequently, it can be assumed that within far-aiming tasks (e.g., golf: 79 Bell & Hardy, 2009), an external focus of attention on specifying information instigated by cognition, may identify more desirable opportunities for action (affordances) within the environment, and consequently allow individuals to organise into a more accurate and efficient attractor states. Similarly, within form tasks (e.g., gymnastics: 21 Lawrence et al., 2011) and proprioceptively guided tasks (e.g., Olympic weightlifting: 37 Anderson et al., 2022), the instigation of an internal focus of attention by cognition may identify more desirable affordances based on internal motor capacities, likewise resulting in more accurate and efficient attractor states. Therefore, direct perception may offer an alternative explanation for focus of attention effects previously associated with Prinz’s (19 1997) common coding.

Secondly, the constrained action hypothesis (20 Wulf et al., 2001) suggests that an external focus of attention facilitates movement accuracy and efficiency by directing individuals’ attention towards environmental aspects, which do not consciously interfere with/constrain the motor system’s ability to self-organise. Consequently, individuals perform more accurate and physiologically efficient actions with reduced cognitive load. However, as identified by Davies (80 2007), the constrained action hypothesis account of external focus effects is already closely aligned with ecological dynamics. The ‘Ecological Dynamics Account of Attentional Focus’ would predict that directing attention to situationally relevant perceptual information (referred to as ‘specifying information’ by Gibson, 2 1979/2014) would facilitate emergent self-organisation in relation to desired outcomes. It is therefore conceivable that attentional foci which are directed towards situationally relevant information, aid performance accuracy and efficiency through enhanced perception-action coupling (see 80 Davids et al., 2012). In essence, individuals benefit from more natural self-organisation of movement coordination, into and between softly assembled attractor states, if given an appropriate focus of attention. Unlike the constrained action hypothesis however, such processes would also explain the performance and efficiency benefits when adopting: (1) an external focus of attention in primarily external information-reliant far aiming tasks (e.g., 60 Zachry et al., 2005); (2) an internal focus of attention in primarily internal information-reliant form or proprioception tasks (e.g., 43 Gottwald et al., 2020); and (3) more versus less task-relevant versions of either focus of attention (e.g., 5 Amini & Vaezmousavi, 2020; 18 Russell et al., 2014; 26 Pelleck & Passmore, 2017). For example, in situations where proprioceptive information is paramount for task success, an external focus of attention may direct conscious attention to task-irrelevant environmental constraints; thus, reducing accuracy and efficiency of actions whilst also increasing attentional load.

Lastly, OPTIMAL theory of motor learning posits that adopting an external focus of attention in conjunction with an appropriate motivational climate (i.e., enhanced expectancies and autonomy) augments the ‘goal-action coupling’ (28 29 Wulf & Lewthwaite, 2016; 2021). Within the Ecological Dynamics Account of Attentional Focus, it is possible to reinterpret the central ‘goal-action coupling’ of OPTIMAL as the interaction between environmental, organismic, and task constraints (82 Newell, 1986). Of note is that the organism may indeed have their own motivational (intention) and focus of attention (attention) constraints, which affect optimal functioning. Motivational constraints may influence the organism’s ability to identify affordances (opportunities for action) that align with their goals, sustain task-relevant attention or inhibit task-irrelevant distractions. Focus of attention constraints may influence whether individual's pick-up or become sensitised to task-relevant information. Indeed, ecological dynamics frames skill acquisition as the education of intention (motivation), education of attention (increased sensitivity to specifying information), and the calibration of perception and action sub-systems. Ecological dynamics is a fusion of ecological psychology and dynamical systems theory (72 Araujo et al. 2006). Ecological psychology (2 Gibson, 1979/2014) posits that perception of energy as lawfully structured information, is direct and meaningful to the organism without interpretation. Movement changes what is perceived by an organism, and perception informs movement. Dynamical systems theory provides a way of understanding the behaviour of complex systems with multiple degrees of freedom without recourse to a central controller or programme (83 Kelso, 2021). Human systems with multiple degrees of freedom (for example all possible movements of muscles, joints, tendons, fascia, neurons) are constrained to move in functional synergies that reduce the overall degrees of freedom. Stable functioning synergies result in patterns of movement that are referred to as system attractor states. Through interaction with tasks and the environment, feedback loops in the shape of physiological and psychological changes in response to action would subsequently lead to adaptations of the organisms' constraints, and ultimately influence action going forward. The changes are more akin to tuning a radio set to be more sensitive to picking up frequencies, than changes in a computer programme made by a programmer. As with more modern and high-tech radios, the changes influence the organism –environment relationship (what can be perceived), not what is stored inside the organism. Learning is a gradual process of becoming attentive to, and interested in, what is going on around us. It is a process that requires us to learn to attend to things, rather than acquiring the knowledge that absolves us of the need to do so (84 Ingold, 2000). Consequently, behaviour emerges through the coupling of movement to perceptual information due to the self-organisation of the movement degrees of freedom.

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Overall, the aforementioned ‘Ecological Dynamics Account of Attentional Focus’ provides a novel and arguably more congruous explanation for focus of attention effects than common coding, constrained action hypothesis, and OPTIMAL (55 Wulf, 1998; 20 2001; 28 2016). As noted by Davies (80 2007), the mechanistic explanations put forward by Wulf and colleagues, somewhat borrow from both information processing (i.e., common coding) and ecological dynamics (i.e., constrained action hypothesis’ championing of self-organisation), while also constraining themselves via assumptions of an external focus of attention’s superiority in all conditions. An ecological dynamics standpoint provides a more conceptually consistent framework, as well as more flexible account in instances where an internal focus of attention may prove desirable. This latter aspect may be in part because, from an ecological dynamics perspective, the distinction between an internal and external focus of attention is less clear-cut. An external focus of attention and its resultant benefits have long been conceptualized as focus on ‘movement effects’ (55 Wulf et al., 1998). However, an affordance is a relationship between an organism (internal aspects) and the environment (external aspects). From an ecological dynamics perspective, it may be beneficial to reconceptualise the beneficial effects of focusing on ‘movement effects’ as representing focus on task-relevant aspects of performance or specifying information, rather than exclusively external information per se as suggested by Herrebroden (17 2022).

**Practical Recommendations**

 There is current debate in the literature surrounding the extent to which practitioners need to fully understand the theoretical underpinnings of skill learning to best inform practice decisions. However, given that this is an area fraught with contention between information processing and ecological psychology perspectives across the academic world alone, it is perhaps idealistic at this stage to expect this from applied practitioners. One philosophical approach involves the metaphor of building a shed: if you build a shed in your garden, whether you believe the earth is flat or spherical, has little influence on the way in which the shed is built. However, there is little doubt that for the best practice conditions to occur, coaches must be able to justify their decision making and articulate the rationale underpinning applied practice decisions.

 When designing effective practice environments in relation to attentional focus, we would advise the following process is adhered to: ‘function before context’ i.e., first consider the primary objective of the practitioner (e.g., skill learning, technical refinement, fostering movements that minimise injury risk, or developing techniques that are under robust pressure) and then consider the context in relation to the motor skill (e.g., far aiming versus proprioceptive tasks), the relevance and proximity of possible foci (where appropriate) and the appropriateness of instructions altogether (see Table 1).

Whilst these practice decisions may well be underpinned by competing theoretical approaches, the shed can still be built. For example, the benefits of a proximal attentional focus for novices can be underpinned by theoretical components of constrained action hypothesis (20 Wulf et al., 2001) as well as Newell’s (86 1987) stages of skill acquisition (i.e., assembling a coordination pattern; gaining control and adaption of coordination; and skilled optimisation of coordination). In assembling coordination patterns, an individual is likely to need and use more proximal information. In the gaining control, during the stabilization phase, learning is focussed on attunement to specifying perceptual information, which can then be exploited in the skilled optimisation phase through effective calibration of action to the perceived information.

The principles of a constraints-led approach can be used to guide practice design that supports an education of focus of attention toward task-relevant information. These principles being: a) goal orientated practice with clear session intentions; b) manipulation of constraints to afford exploration of opportunities for action; c) representative learning design that includes perceptual information that will be available in performance; and d) repetition without repetition, encouraging the development of adaptable and effective movement solutions.

Table 1. Practical solutions to support applied practice.

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| **Applied Challenge / Context** | **Applied Practice Solution** | **Practical Example** | **Theoretical Rationale** | **Supporting Evidence** |
| *When there is a decision to be made to select the most appropriate external focus in a skill requiring coordination of several body parts* | Proximal external focus when working with individuals in early (cognitive) stages of learning and distal external focus when working with individuals in late (autonomous) stages of learning | A novice focusing on the racquet motion during a tennis serve versus an expert focusing on the intended ball trajectory  | Focusing proximally allows novices to attend to skill-relevant information and assemble optimal coordination patterns. Focusing distally promotes motor automaticity for experts. In the gaining control, during the stabilization phase, learning is focussed on attunement to specifying perceptual information which can then be exploited in the skilled optimisation phase through effective calibration of action to the perceived information | 79 Bell & Hardy (2009); 15 Singh & Wulf (2020); 87 Wulf & Prinz (2001) |
| *When there is a need to ‘simulate’ an external focus because this doesn’t exist naturally*  | Using visual images to replace body parts | Imaging a ‘platform’ in place of the forearms during a volleyball pass | Prevents individuals focusing on body-centred information and constraining actions | 25 Liao & Masters, (2001); 24 Singh & Wulf (2022) |
| *When a meaningful external focus cannot be easily identified* | Adopting a holistic focus of attention | Focusing on making yourmovement ‘feel explosive’ in a standing long jump task | Prevents individuals focusing on body-centred information and constraining actions | 88 Abedanzadeh et al. (2022); 23 Becker et al. (2018); 89 Saemi et al. (2022);90 Zhuravleva & Aiken, 2023 |
| *To identify clear session intentions* | Goal-orientated practice | Intention considered the most important constraint on affordance perception  | Frames interactions with task and environment  | 70 Kelso, 1995 |
| *When the demands of competition must be matched to practice* | Representative learning design | Ensuring that task-relevant information is available in practice. For example, designing tennis practice to contain more information that is representative of competitions | Supports attunement to the information that will be specifying in competition | 91 Brunswick 195692 Krause et al, 2019)93 Regan (1997) |
| *When there is a need to enhance the extent to which skills are adaptable to changing environments* | Promoting self-organisation | Using constraints manipulation to destabilise current attractor states without using declarative instructions for body awareness | Developing dexterity or adaptiveness to constantly changing external information. Reducing the chances of choking under pressure through reinvestment of conscious control | 94Gray, 2018.  |
| *To ensure coupling to specifying (task-relevant) perceptual information* | Variability of practice | Using varied practice to ensure that information that is present in an environment but not reliable or specifying (such as distance for ball hitting), is not tightly attuned to, but instead through learning, more reliable information in the form of ‘time to contact’ is used instead | To support the attunement to specifying, rather than incidental, information during practice by ensuing that only specifying information is available in all practice environments | 95 Gray (2021) |
| *Affording exploration of movements and perceptual landscapes* | Manipulating constraints to the task, environment, and organism | Using occlusion goggles to educate attention to more effective information sources such as more distal target related information such as the movement of other players. Or using constraints to move attention away from internal control by removing the need for explicit instructions | Constraints can be manipulated to change the available information sources – focusing education of attention to more specifying information.Manipulating constraints can also reduce the likelihood of using internal, form-based information, thus supporting self-organisation | 96 Oudejans (2012) |
| *To prevent injury caused by long-term technical errors within a movement* | Five-A model of technical refinement  | Using a process of analysis and bodily awareness to correct adverse elbow abduction in the weightlifting snatch movement  | Supports error detection and correction via a process of analysis, awareness, adjustment, (re)automation, and assurance | Carson and Collins’ (40 2011; 41 2014; 42 2016) |
| *When refining motor skills by altering biomechanics of movements that are already well established*  | Facilitative somaesthetic awareness | Using internal focus verbal cues to “run with a flat foot” during gait retraining in running | Supports error correction and enables individuals to ‘relearn’ movements  | Gottwald et al. (43 2020); Moore et al. (46 2019); Toner & Moran (38 2015) |
| *When developing broader psychological interventions to enhance self-efficacy or positive affect* | Using an external focus of attention combined with enhanced expectancies for success based on OPTIMAL theory of motor learning | Placing a cone to represent normative standing long jump data for individuals in the bottom 5th percentile in a standing long jump and directing individuals to try to jump as far past the cone as they can | Addresses the complex interaction between motivational and attentional factors that facilitate skill learning via goal-action coupling | Simpson et al. (66 2020); Wulf & Lewthwaite (28 2016; 29 2021) |

**Future Research Directions**

Although the fundamental principle of adopting internal or external foci of attention is simple, there remain ample avenues for future research. Above all else, the presently proposed ecological dynamics-based mechanisms for focus of attention effects are conjecture. However, so are information processing-based explanations until it is understood whether underlying neurophysiological mechanisms resemble information processing or ecological dynamics (97 Renshaw et al., 2019; 98 Woods et al., 2020). Out of the rather limited number of studies that have investigated the cortical processes underlying attentional foci, results suggest that internal foci of lesser task relevance may: (1) prevent visual inflow of environmental information to shield internal body-focused processing, via reductions in posterior alpha power (27 Parr et al., 2022; 99 Sherman et al., 2021); (2) induce volitional control of attention to adjust behaviour responses to feedback via decreased frontal midline theta (100 Cavanagh & Frank, 2014; 27 Parr et al., 2022); and (3) unbind muscles from a synergistic control strategy via reduced beta corticomuscular coherence between the contralateral motor cortex and effectors (27 Parr et al., 2022). Importantly, these neural mechanisms align with the proposals of ecological dynamics; the selective shielding/prioritisation of environmental versus organismic constraints, cognition’s supervision of attention to benefit perception for action, and binding/unbinding of synergistic control strategies, support the notion of an organism’s self-organisation in response to its environment and task. Future research should continue to elucidate the neural mechanisms underlying both focus of attention and ecological dynamics, to inform theoretical understanding.

Another benefit of an ecological dynamics standpoint is its ability to account for results that are ill explained by common coding (19 Prinz, 1997), constrained action hypothesis (20 2001), or OPTIMAL theory (28 29 Wulf & Lewthwaite 2016; 2021). Seminal literature’s staunch advocacy of an external focus of attention (1 Wulf, 2013) has resulted in comparatively little evaluation of instances where an external focus of attention may not be superior. However, noteworthy exceptions include investigations into internal foci for somaesthetic awareness (38 Toner & Moran, 2015), holistic focus of attention in instances without a clear external movement effect (Becker et al., 2017), and developmental benefits of adopting an internal focus of attention in proprioceptive sports (Olympic Weightlifting; 37 Anderson et al., 2022). Overall, a body of literature is beginning to emerge which aligns with the concepts of ecological dynamics in suggesting that foci other than an external focus of attention can be facilitative. Future research should make concerted efforts to further understand applied and theoretical nuances within focus of attention.

With regards to applied nuances, the ecological dynamics-based framework has demonstrated itself popular within talent development research for its pertinent emphasis of multivariable effects (e.g., 101 Dimundo et al., 2021). It is proposed that no single independent factor can account for real-world differences in performance; instead, it is the combination of task (e.g., practice history), organism (e.g., anthropometrics and technical/tactical awareness), and environmental (e.g., relative age and sociocultural) constraints (72 Araujo et al. 2006). Consequently, ecological dynamics offers a useful framework through which to investigate focus of attention effects observed in highly applied (i.e., ecologically valid) settings. For example, when comparing external versus internal focus effects in a complex five-part gymnastics floor routine, assessed via the Federation Internationale de Gymnastique Code of Points, 21 Lawrence et al., (2011) observed no significant difference in performance based on attentional focus. In the absence of a more nuanced theoretical framework, null findings in the ecological study of Lawrence et al. were subsequently argued to be a product of methodological limitations (22 Abdollahipour et al., 2015; 1 Wulf, 2013). However, it is possible that nuanced interactions between a multitude of variables meant that an internal focus of attention was able to yield unique benefits for participants. Going forward, ecological dynamics provides a promising framework for investigations in ecologically valid settings to avoid interpretational/publication bias.

Lastly, given doubts raised by recent research concerning an external focus’ ubiquitous superiority over an internal focus (e.g., 37 Anderson et al., 2022; 43 Gottwald et al., 2020; 38 Toner & Moran, 2015), it may be timely to re-evaluate what constitutes an optimal focus of attention, depending on skill and individual differences. To-date, investigations concerning possible foci of attention have been ‘top down’ in their exploration of available foci; researchers traditionally identified and prescribed foci adopted by participants. Comparatively little research has attempted to utilise a ‘bottom up’ approach (e.g., 35 Orr et al., 2021), wherein optimal/preferred foci are identified by participants themselves. Such approaches may help identify further nuances to the focus of attention effect, in addition to distance (14 Mcnevin et al., 2003), task relevance (26 Pelleck & Passmore, 2017; 18 Russell et al., 2014), and breadth (50 Becker et al., 2018). Promising avenues to address this omission in current literature include think aloud protocols (103 Eccles & Arsal, 2017) and virtual reality (104 Neuman et al., 2021). These methods respectively allow researchers to better assess and manipulate contextual information to ascertain novel nuances within the attentional foci adopted by participants.

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