Title: Considering the role of cognitive control in expert performance

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Abstract

Dreyfus and Dreyfus' (1986) influential phenomenological analysis of skill acquisition proposes that expert performance is guided by non-cognitive responses which are fast, effortless and apparently intuitive in nature. Although this model has been criticised (e.g., by Breivik, 2007; 2013; Eriksen, 2010; Montero, 2010; Montero & Evans, 2011) for over-emphasising the role that intuition plays in facilitating skilled performance, it *does* recognise that on occasions (e.g., when performance goes awry for some reason) a form of 'detached deliberative rationality' may be used by experts to improve their performance. However, Dreyfus and Dreyfus (1986) see no role for calculative problem solving or deliberation (i.e., drawing on rules or mental representations) when performance is going well. In the current paper, we draw on empirical evidence, insights from athletes, and phenomenological description to argue that 'continuous improvement' (i.e., the phenomenon whereby certain skilled performers appear to be capable of increasing their proficiency even though they are already experts; Toner & Moran, 2014) among experts is mediated by cognitive (or executive) control in three distinct sporting situations (i.e., in training, during pre-performance routines, and while engaged in on-line skill execution). We conclude by arguing that Sutton, McIlwain, Christensen and Geeves' (2011) 'applying intelligence to the reflexes' (AIR) approach may help to elucidate the process by which expert performers achieve continuous improvement through analytical/mindful behaviour during training and competition.

Keywords: expertise, Dreyfus, embodiment, cognitive/executive control

Considering the role of cognitive control in expert performance

Television commentators often marvel at the ease and grace with which great athletes like Tiger Woods and Roger Federer execute complex skills under intense competitive pressure. We may watch Woods propel a tee-shot 320 yards or Federer flash a forehand drive past the despairing reach of a beleaguered opponent and wonder how these skills can be executed with such breathtaking efficiency. Inspired by this question, scholars such as motor learning theorists, cognitive neuroscientists and philosophers of sport have sought to uncover the precise cognitive mechanisms which mediate the apparently effortless but consistently accurate execution of these complex skills. Research in this area has been heavily influenced by information-processing theories of skill acquisition (e.g., Fitts & Posner, 1967) which argue that skill learning starts with controlled processing (which is slow, deliberate and effortful in nature) and gradually leads to the development of "automaticity" (an umbrella term that refers to performance that is uncontrolled, unconscious, efficient and fast; Moors, 2013). According to Fitts and Posner (1967), if an expert golfer's attention is called to his muscle movements before an important putt "he may find it unusually difficult to attain his natural swing" (p. 15). Similarly, Dreyfus and Dreyfus' (1986) highly influential phenomenological analysis of skill acquisition argues that expert performance proceeds "without calculating and comparing....what must be done, simply is done" (2004, p. 253). Clearly, the Dreyfuses propose that skilled performance is guided by non-cognitive responses (involving no recourse to mental representations) which are fast, effortless and intuitive in nature.

Challenging this latter proposition, however, is an emerging body of empirical evidence (e.g., Nyberg, in press; Ravn & Christensen, 2014; Suss & Ward, 2010) and theory (e.g., Breivik, 2013; Montero, 2010; Toner & Moran, 2015) which suggests that mindful behaviour (including awareness of bodily movement or motor execution) is a ubiquitous feature of elite athletes' training and performance routines. Interestingly, Ericsson (2006) has argued that expert performers actually seek to avoid *automaticity* by developing "increasingly complex mental representations to attain higher levels of control of their performance" (p. 685). In a similar vein, Ravn and Christensen (2014) suggest that to optimise their performance athletes have to "experiment with and research their moving body" (p.463). So, how may we reconcile these conflicting perspectives concerning the role of "mindedness" in guiding expert performance? Is such performance guided predominantly by intuition or do elite athletes engage in mindful activity when practicing and performing complex movements?

In seeking to resolve this conflict between different accounts of expert motor behaviour, a number of theorists (see Breivik, 2007, 2013; Christensen, Sutton & McIlwain, in press; Eriksen, 2010; Montero, 2010) have criticised the Dreyfus and Dreyfus model for over-emphasizing the role that intuition plays in facilitating skilled performance and for failing to adequately account for how conscious and mindful activity can sculpt embodied routines during training and on-line performance. However, it is important to note that Dreyfus' model does acknowledge that deliberation can be used by expert performers when the 'time permits' or when things go awry. For example, Dreyfus (1997) acknowledged that deliberate action may be required when we encounter 'unready-to-hand' performance such as 'when a piece of equipment is missing or when the situation is abnormal' (p. 27). On such occasions, 'representational intentionality' (use of deliberate consciousness) may act as a secondary way of dealing with the world when "the primary relation breaks down" (Breivik, 2007, p. 125). Although the Dreyfuses recognise that 'detached deliberative rationality' may help the skilled performer when things go awry, they see no role for calculative problem solving or deliberation (i.e., drawing on rules/ principles or mental representations) when things are going well. Unfortunately, the latter perspective appears unable to account for recent findings (e.g., Carson, Collins, & MacNamara, 2013; Cotterill, Sanders, & Collins, 2010) which suggest that 'continuous improvement' (i.e., the phenomenon whereby certain skilled performers appear to be capable of increasing their proficiency even though they are already experts; Toner & Moran, 2014) at the elite level of sport involves the use of calculative problem solving (including drawing on mental representations or propositional knowledge; see Stanley & Krakauer, 2013; Toner, 2014) to help to refine disrupted (e.g., due to injury) or inefficient movement patterns during practice and the use of mindful activity (e.g., cue words) to guide embodied routines during competitive performance. In the latter case, mindful behaviour is not 'detached' but occurs while the performer is actually executing the skill (i.e., and hence, when there is little time available for deliberation).

Given the emergence of this latter evidence, it is surprising to note that few researchers have considered how skilled athletes might use cognitive (or executive) control to maintain or improve their performance proficiency (for one notable exception, however, see Christensen et al. in press). This generic phrase "cognitive control", refers to "the functions of the cognitive system that allow people to regulate their behaviour according to higher order goals or plans" (Vebruggen, McLaren, & Chambers, 2014, p. 497). Typically included under this heading are cognitive processes that are conscious and intentional in nature such as the use of rules or principles and mental representations (i.e., images). The current paper seeks to address this gap in the literature by drawing on empirical evidence and phenomenological description to explain how skilled performers might productively utilise cognitive control in three distinct sporting situations: (1) during training activities when the performer is seeking to improve performance proficiency by altering an 'attenuated' habitual movement (2) during the planning/strategising that occurs in pre-performance routines during on-line competitive performance and (3) when performers use cue words or 'instructional nudges' (i.e., explicit verbal phrases) during skill execution to re-chunk patterns of movement. We conclude the paper by arguing that Sutton, McIlwain, Christensen, & Geeves' (2011) 'applying intelligence to the reflexes' (AIR) approach may help to explain how skilled action is guided by the effective use of analytical/mindful (i.e., conscious and controlled processing) behaviour during training and competition.

Let us start by outlining Dreyfus and Dreyfus' (1986) phenomenology of everyday expertise. Briefly, these authors propose that there are 5 explicit stages in the progression from novice to expert in any domain of expertise that is "unstructured" (e.g., management, nursing, teaching, driving). The first three stages (i.e., *novice*, *advanced beginner* and *competence*) emphasize rule-following behaviour. At the novice stage, an instructor will often break down the task environment into context-free features and then provide the beginner with rules for guiding actions on the basis of these characteristics. The advanced beginner learns to use rules which include both self-experiential situational components alongside the previously acquired context-free rules. Competence is reached when learners realise how to devise a plan that allows them to choose or ignore those elements of a situation that may be considered important or unimportant.

Dreyfus and Dreyfus's postulated fourth (i.e., *proficient*) and fifth (i.e., *expertise*) stage are characterised by the learner's ability to make more subtle and refined discriminations. The learner can now see what needs to be achieved rather than having to consciously and deliberately calculate which of several possible alternatives should be selected. However, the proficient performer has yet to have had sufficient experience with a wide variety of responses to each of the situations he/she encounters to be able to respond intuitively. So, although proficient performers may be able to identify the important features of a situation they remain reliant on detached rule-following to help them decide what to do. By contrast, experts possess a vast repertoire of situational discriminations which allow them to intuitively see how to achieve their goal. Dreyfus and Dreyfus (2004) sought to capture the progression from novice to skilled performer by arguing that the beginner makes "judgements using strict rules and features, but with talent and a great deal of involved experience, the beginner develops into an expert who sees intuitively what to do without applying rules and making judgements at all" (p. 253). As such, the move from novice to expert requires a gradual relinquishing of one's reliance on explicit rules. Dreyfus and Dreyfus posit that skilled performers neither rely on ‘verbally articulable propositions’ (behind their decisions and action), nor require any conscious access to mental representations which guided performance during the initial stages of skill acquisition. Instead, an “expert’s skill has become so much a part of him that he need be no more aware of it than he is of his own body” (Dreyfus & Dreyfus, 1986, p. 30). According to Dreyfus (2007), “mindedness is the enemy of embodied coping” because “there is no place in the phenomenology of fully absorbed coping for mindfulness … there are only attractive and repulsive forces drawing appropriate activity out of an active body” (p. 353).

Although a number of influential skill acquisition models (e.g., Fitts & Posner, 1967) used the term “automaticity” to describe the absence of attentional processing which accompanies expert performance, Dreyfus and Dreyfus preferred the term ‘intuitive’ which they believe best captures the unreflective, immediate and situational responses exhibited by skilled performers. These authors postulated that such intuitive responses are performed not only without any cognitive control but without any recourse to mental representations. The Dreyfuses’ emphasis on the key role that intuition plays in guiding expert performance was heavily influenced by the work of the phenomenologists Heidegger and Merleau-Ponty. To illustrate, Dreyfus’ work is rooted in two seminal concepts in Merleau-Ponty’s *Phenomenology of Perception* (1962) – the “intentional arc” and acquiring a “maximal grip”. The *intentional arc* portrays the close connection between the agent and the world and is used to convey Dreyfus’s (2002) belief that acquired skills are ‘stored’ not as “representations in the mind, but as dispositions to respond to the solicitations of situations in the world” (p. 367). The term *Maximal grip* describes how the body will respond to these solicitations in a way that will bring the current situation closer to the performer’s/agent’s sense of an optimal gestalt. Merleau-Ponty (1962) believed that these preceding concepts allow us to understand how the active body may inhabit the world without having to draw on mental representations.

Unfortunately, by rejecting the role of mindedness, Dreyfus’ model cannot easily account for a significant volume of empirical evidence which indicates that skilled performers have been shown to retain an awareness of their movement during on-line skill execution (see Jackson & Csikszentmihalyi, 1999). Moreover, all sports allow athletes the opportunity to reflect on their competitive performance and critically consider (in the practice or performance context) how they might refine, alter and improve their movement proficiency (e.g., see Ravn & Christensen, 2014). Building on this idea, we seek to contribute to this emerging body of literature by providing a context-sensitive portrayal of how expert performers (drawing heavily on the first author’s phenomenological description of skill acquisition and performance in golf and on relevant empirical findings) respond to the situation-specific demands that they encounter in the training and performance environment.

Although Dreyfus and Dreyfus's (1986) model postulates that intuitive behaviour is the key mechanism guiding expert performance, the authors acknowledge that "when time permits and outcomes are crucial, an expert will deliberate before acting" (p.31). However, these authors explain that typically such "deliberation does not require calculative problem solving, but rather involves *critically reflecting on one's intuitions*" (Dreyfus & Dreyfus, 1986, p. 33; our italics). This form of deliberate thinking differs from that of the novice (who typically focuses on rules or principles) as the expert reflects on the goal that seems evident to him/her and upon the action appropriate to achieve that goal. It is important to note that this form of deliberation does not involve making judgements on the basis of memory-based recognition or consciously recalling similar experiences which may be brought to bear on current problems. Instead, this detached reasoning about one's intuitive or habitual performance allows experts to check their intuitions during performance and helps them to respond even more intuitively should they encounter similar situations in the same competitive event or during future performances. Unfortunately, few researchers have sought to understand the concept of cognitive control (but see Morton, Ezekiel, & Wilk, 2011) and so we know little about the mechanisms or time requirements necessary to mediate this activity in the sporting domain.

Dreyfus and Dreyfus (1986) also acknowledge that deliberate action may be useful in unusual situations which prompt performance failure, such as slipping when the floor is wet. On such occasions, 'thematic intentional consciousness' (i.e., deliberate attention to an object) might help us repair, design or test equipment (Dreyfus, 1991, p. 70). When we encounter some form of difficulty with our habitual or intuitive actions, Dreyfus (1991) argues that "we must pay attention and so switch to deliberate subject/object intentionality" (p. 69). Although Breivik (2007) agrees with Dreyfus on this point, he believes that there are a much wider variety of situations that require deliberate attention. Such circumstances include "situations in which we consciously try to improve performance in order to become very good at something, as is the case in sport, science, warfare, and work" (Breivik, 2007, p. 125). By placing such emphasis on the role embodied coping plays in guiding expert performance, Dreyfus may have underestimated the importance of top-down processes (such as planning, reflecting, refining) in helping improve performance at the elite level. We agree with Breivik (2007, 2013) and other recent commentators (see Montero, 2010; Shusterman, 2009) who argue that the learning process is never entirely complete. Indeed, it would seem that expert performers seek to avoid 'arrested development' (see Ericsson, 2006) and try to counteract automaticity by devising training activities that are aimed at "reaching a level just beyond the currently attainable level of performance by engaging in full concentration, analysis after feedback, and repetitions with refinement" (Ericsson & Ward, 2007, p. 349). These training activities will inevitably require a high degree of conscious attention and mindful action as the athlete seeks to consciously and deliberately refine or alter aspects of their performance – an apparently ubiquitous feature of elite performer's training regimes (see Collins, Morriss, & Trower, 1999).

According to Breivik (2007), by portraying people as mindlessly performing their daily duties Dreyfus ignores this preceding evidence and forgets the "vast amount of conscious activity that surrounds the mindless coping" (p. 126). Instead, Breivik (2007) suggests that an interrogation of our own experiences shows that "we are much more flexible switching between absorption and deliberation, mindless coping and conscious improvement on a regular basis" (p. 127). Dreyfus presents a theory of expert action which is based on the performance of everyday activities (that are often performed intuitively) such as driving a car and from here he extrapolates to expert level actions such as flying a fighter plane. One of the main aims of the current paper is to extend recent work (e.g., Breivik, 2007, 2013; Montero, 2010) by drawing on theory (e.g., Shusterman, 2011; Sutton et al. 2011), empirical evidence (e.g., Collins et al. 1999), and phenomenological description, to demonstrate that the maintenance and improvement of skilled action is hugely dependent on the performer's ability to utilise mindful modes of bodily awareness – even in the midst of skill execution where very little time is available. We argue that this latter process will inevitably require the performer to engage in cognitive control when seeking to guide embodied routines in the training and competitive context. In constructing this argument, we draw on Sutton et al.'s (2011) suggestion that there are at least 3 occasions when mindedness can play a role in influencing expert performance. These authors argued that the mind can intervene during 'offline' strategic rehearsal (e.g., pre-performance routines) and during moments of breakdown (e.g., when we acquire 'attenuated' movements), but they also ask us to consider how "thought, talk, or memory can interact with practised embodied skill at a range of timescales, both in real time at the height of performance, and in temporally complex feedback loops" (e.g., during on-line competitive performance, p. 93). We will illustrate three specific occasions (i.e., training, pre-performance routines, on-line skill execution) when expert performers may use cognitive control to maintain or improve their current level of performance proficiency.

Cognitive control in training

Let us start by considering the role cognitive control may play during expert performers' *training regimes*. Dreyfus and Dreyfus' (1986) model focuses solely on things that happen in the heat of competitive action and ignores the considerable amount of mindful activity that takes place during training, preparation and evaluation of performance (Breivik, 2013). As a result, they fail to consider the possibility that experts are used to *thinking* and *doing* at the same time. To illustrate, research evidence (e.g., see Helsen, Starkes, & Hodges, 1998) indicates that at least 4,000 hours of deliberate practice (i.e., sustained engagement in training activities that are "very high on relevance for performance, high on effort, and comparatively low on inherent enjoyment"; Ericsson, Krampe, & Tesch-Römer, 1993, p. 373) may be necessary before an athlete can reach a world-class level of performance. This form of practice requires high levels of intense concentration so athletes can gradually improve their performance by correcting specific technical weaknesses (Ericsson, 2006). Moreover, once athletes reach such a level of performance, deliberate practice does not cease. For example, Deakin and Cobley (2003) found that elite-level figure skaters devoted conscious attention to the improvement of inefficient jumps and spins during practice. Although the Dreyfusian perspective argues that only novices focus on bodily movements when performing, empirical evidence suggests that conscious and deliberate attempts to refine and improve one's movement proficiency remain a ubiquitous feature of elite performers' training regimes (see Collins et al. 1999; Ravn & Christensen, 2014).

There appear to be two specific reasons why elite athletes may use cognitive control to alter and improve their technique during practice. *First*, a key feature of continuous improvement at the elite level of sport involves athletes' desire to learn 'new and better techniques' (Breivik, 2007, p. 127). Elite performers seek continually to improve their overall performance and conscious attempts to alter and refine aspects of their movement/technique seem crucial in helping them reach new levels of excellence (see Montero, 2010). For example, having won the USPGA Championship at the age of 25 (and achieving the status of number one ranked golfer in the world), Martin Kaymer decided to alter his technique so that he could hit a greater variety of shots (i.e., hit both a 'fade' which involves a left-to-right trajectory and a 'draw' which involves a right-to-left trajectory). Although Kaymer experienced a 'slump' during the initial stages of making these swing changes he recently achieved a spectacular 8 stroke victory in the 2014 US Open Championship. Having altered his technique Kaymer now believes he is 'more of a complete player' (Shipnuck, 2014). Altering habitual movement patterns that have brought an athlete great success can be a risky strategy (i.e., if a systematic process is not followed; see Carson, Collins, & Jones, 2014) but Montero (2010) argues that winning might require not simply performing as one has in the past, but performing better than ever and taking that risk is the opposite of “simply spontaneously [doing] what has normally worked” (Dreyfus & Dreyfus, 2004, p. 253). Even those who excel at the very highest level of sport appear motivated to continually improve their technique and movement efficiency. In fact, the preceding evidence would suggest that a reliance on intuition or ‘absorbed coping’ is not enough to maintain a high level of performance proficiency.

Second, habitual behaviours may be prone to sudden or volatile disruptions (through injury, fatigue, growth, aging; see Bissell, 2013; Eden, 2013). This means that performers will often “lapse into bad habits of performance or face new conditions of the self...and new environments in which we need to correct, relearn, and adjust our habits of spontaneous performance” (Shusterman, 2008, p. 138). Consequently, performers have little choice but to consciously reflect on the efficacy of their movement (in the practice context) when habitual movement breaks down. Indeed, reports abound of elite athletes having to consciously alter their habitual movement in order to maintain performance proficiency. For example, Bernhard Langer, the two-time major golf champion, twice altered his putting stroke in order to combat the ‘yips’ (a movement disorder which affects motor control; see Smith et al., 2003). More recently, Rory McIlroy (a four-time major championship winner) sought to extricate himself from a performance slump by consciously altering a specific aspect of his golf swing (Carter, 2012). This process involved McIlroy’s coach drawing his attention to the difference between the inefficient movement and the more desirable or efficient one. Within weeks of making the technical adjustment McIlroy romped to a spectacular 8 stroke victory in the USPGA championship.

What are the cognitive mechanisms that allow elite athletes to improve their performance proficiency by using reflective modes of bodily awareness? First of all, performers may use ‘somaesthetic awareness’ (see Shusterman, 2008) to identify problematic movements during competition or when coaches are telling them that they are “doing something awkward, peculiar, or detrimental” (Shusterman, 2012, p. 212). This form of awareness encourages performers to attend to the “proprioceptive feel of what they are doing” (2009, p. 138). Such a focus of attention requires performers to become consciously aware of their movement and whether it is causing discomfort or an outcome that is unusual or undesirable. Having identified the ‘attenuated’ habit, the performer will often work alongside a coach in seeking to alter and refine the problematic movement. Empirical evidence has shown how coaches can construct practice activities that allow athletes to consciously refine and improve their movement efficiency (e.g., Carson et al. 2014; Hanin, Korjus, & Jouste, 2002; Hanin, Malvela, & Hanina, 2004). In each of these studies, researchers helped athletes refine their movements by increasing their conscious awareness of the kinesthetic differences between currently problematic and desired movements. For example, Collins et al. sought to improve the performance of an Olympic javelin thrower whose technique had been disrupted by either unconscious inhibition (e.g., remaining concerns over previous injuries) or trace delay (i.e., an inability to access the motor program for the correct or desired movement). Collins et al. used 'contrast' drills to increase the athlete's conscious awareness of the correct versus incorrect movement positioning and to help internalise key movement characteristics. This process required the athlete to become increasingly mindful (therefore abandoning a reliance on spontaneity or intuition to guide the movement) and to ensure that throws were completed using the correct (old) and incorrect (current) positioning, thereby drawing his attention to the difference between the respective movements. Kinematic analysis was also used to show how the technique had improved and the regained technique was still evident two years following the intervention. Importantly, this intervention resulted in a return to throwing distances that were achieved prior to the emergence of the inefficient movement pattern.

The Dreyfusian perspective might argue that having habituated the new movement (after extensive practice) the performer may relinquish any form of bodily awareness and allow spontaneity or intuitive processes to guide on-line performance. However, even when aspects of the new movement have been successfully automated, the performer must remain 'somaesthetically aware' of their movement efficiency during competitive situations so that they can identify any disrupted habits that might require adjustment (see Ravn & Christensen, 2014). Unfortunately, the kind of 'mindless coping' that Dreyfus associates with skilled performance may actually prove counterproductive by encouraging the athlete to forget about the "consciousness and focus that is needed to stay on top and follow through at the highest performance level that one is able to reach" (Breivik, 2013, p. 95).

Cognitive control during pre-performance routines in competitive contexts

Even when performing and moving proficiently, cognitive activities such as conscious or detached deliberation are commonly involved in the planning and strategising which takes place during the pre-performance routine in closed-skill sports. This brings us to the *second* sporting situation in which the performer may productively utilise cognitive control. As Breivik (2013) points out "if one has time, one can reason and test out several options, weigh them and then decide" (p. 94). Recent evidence suggests that this is precisely what happens during elite golfers' pre-performance routines. To illustrate, in a naturalistic investigation of the attentional foci adopted by elite golfers during competition, Bernier, Codron, Thienot and Fournier (2011) found that participants engaged in deliberate planning prior to executing a stroke. For example, one golfer revealed that to play a specific shot “I stand behind the ball, I focus on the slopes, I analyze their inclination degrees and their directions” (p. 334). When reporting his pre-performance routine for a tee shot another golfer stated that “I start to take in information: the distance, the wind. I place my tee, and just after that I focus on the target I have chosen” (p. 335). Interestingly, in the latter example, the elite golfer started his pre-performance routine by deliberately picking a specific target to aim at and then established a kinaesthetic feel for how he wanted to release the club through impact. Next, he envisaged the desired ball trajectory and then took a final glance at the target before initiating the stroke. Here, the golfer thought about his movement mechanics (i.e., the kinaesthetic ‘feel’) and considered how the elements (i.e., wind) were likely to influence the trajectory and shape of his shot. Of course, there may be occasions when the performer spends little time deliberating about their movement mechanics and successfully executes the task by making the necessary adjustments in a relatively automated manner.

These phenomenological descriptions draw attention to the important role that proprioception or kinaesthesia plays in readying the expert performer for movement execution. Indeed, having calculated the distance remaining to the target and chosen the appropriate club to hit the ball the requisite distance, the golfer will proceed to take a number of practice swings in order to establish a ‘kinaesthetic feel’ for how the stroke needs to be executed. This appears to be an important function of the pre-shot routine. For example, Nicholls and Polman (2008) used a think-aloud protocol to examine elite golfers coping strategies during on-line performance and found that one performer used practice swings to ‘get a feel for the yardage’ (p. 290). During this process there may be little conscious thought relating to the details of the mechanics of the movement. That is, the expert (when swinging the club efficiently) may devote little conscious attention to the step-by-step processes involved in the swing but will merely try to establish a proprioceptive feel for the tempo and rhythm with which they intend to execute the stroke.

Nevertheless, even when movement mechanics are operating efficiently, conscious reflection can play an important role in the performer’s shot selection and their decisions concerning how they may best meet contingent contextual demands. Although Dreyfus and Dreyfus (1986) acknowledge that ‘detached deliberative rationality’ can improve the performance of the intuitive expert, they argue that no rules or principles are “used to arrive at conclusions, and so it is not the sort of calculative rationality used by the beginner or competent performer as a surrogate for intuitive understanding” (p. 41). However, we contest this claim by pointing to evidence which demonstrates that elite performers do engage in a form of ‘calculative rationality’ when making decisions in the performance context. For example, Cotterill et al (2010) reported that elite golfers used their pre-performance routine to consider the risk associated with a particular choice of shot. Like the master chess player, the skilled golfer will often think a step ahead and consider the potential danger posed by an ‘approach shot’ that misses a specific side of the green/target (i.e., therefore considering the difficult pitch shot they would face having missed the target and ending up on the ‘wrong side’). This evaluative process usually involves a number of steps. First, the performer may work out the precise distance in yards remaining to the flag/pin. Next, one must critically consider where the danger lies around the target. For example, if the back of the green gives way to a steep drop then it is important to remind oneself not to overshoot the target (as this would ensure that the next shot is extremely difficult). The performer may now have calculated that 155 yards remains to the pin and that this is located 5 yards from the back of the green. This position could, for some golfers, leave them ‘in-between’ clubs if they usually hit a 9 iron 150 yards and an 8 iron 160 yards. Because overshooting the green would almost certainly prove costly, the golfer may make a conscious and deliberate decision to hit a 9 iron and accept that this would come up slightly short of the target. Overall, this seems like the most prudent decision and would ensure that the expert is left with a ‘birdie’ putt while reducing the likelihood that they will overshoot the target and risk ‘dropping a shot’. While there are a number of factors deliberated upon in this example this decision is often made in a matter of seconds. Having calculated the risk associated with a particular stroke, and determined how best to avoid it, the golfer can focus on hitting the ball the requisite distance and to the desired location.

Although little thought might be given to movement mechanics in the preceding example, there are other occasions when the expert performer is presented with a challenge which may require them to consciously reflect on their movement and critically consider how they may need to adjust their embodied routines to meet situation-specific demands. These challenges may involve being presented with relatively unusual or unfamiliar situations in the performance context (Eriksen, 2010). Consider, for example, the situation that faces the expert golfer who has hit a wayward tee shot which misses the right-hand side of the fairway on a hole which ‘dog-legs’ (i.e., it bends, changing direction at some point along its course) left-to-right. Here, the performer might find that their route to the pin (which is on the right-hand side of the green) is severely impeded by trees or overhanging branches. Nonetheless, if there is an opportunity to reach the green by severely ‘shaping’ a shot from left-to-right (thus avoiding the tress) then the skilled performer is likely to choose this option. This particular stroke may represent a challenge as it requires the performer to produce a movement pattern which is markedly different to their habitual or ‘normal’ movement. Here the performer might be required to consider how much side-spin they need to impart on the ball in order to produce the desired flight (i.e., left-to-right). An additional issue may concern the ideal trajectory (i.e., hitting it low) and the need to ensure that the ball does not catch the overhanging branches. There may be a number of steps taken by the performer in preparation for this kind of shot. First, it is likely that mental imagery will play a key role in helping the golfer to forge a clear picture of the type of shot that must be struck in order to reach the target. This process typically involves standing directly behind the ball, in line with the intended target, and forming a visual image of the ideal trajectory and shape of shot. The golfer might also engage in self-talk at this point - reminding oneself of the need to start the ball on the right line and to ensure it is hit with a sufficiently low trajectory. Having made a decision regarding the type of shot required the expert is likely to perform a number of practice swings and seek to establish a 'feel' for the type of movement which is necessary to produce such a severe (and atypical) flight pattern.

According to Dreyfus, an expert faced with this latter situation would not draw on a discrete mental representation but would recognise some gestalt-like pattern that he/she must follow (Breivik, 2013). However, we question this latter perspective and, instead, agree with Sutton's (2007) view that the expert may be capable of remembering "particular relevant instances to bring to bear on current problems" (p. 773). Here, the expert may search through a space of possible actions. For example, I may recall having recently executed a similar stroke and conjure up an image or kinaesthetic feel of what it was like to perform that particular shot. This process might be akin to the reactivation of bodily sediment where the performer may seek to bring the feeling of previously enacted movements back into awareness where they can come to "inhabit them, rather than letting that sediment play out anonymously within me" (Sutton et al. 2011, p. 94). To illustrate, an elite golfer in Bernier et al.'s (2011) study revealed that he sought to correct a poor shot by calling to mind the "sensations that I should feel when making contact with the ball and to focus on the ball-height by imagining the whole trajectory" (p. 335). Similarly, Nyberg (in press) found that when elite freeskiers are in the midst of a jump they are simultaneously aware of, and make reference to, bodily experiences from previous jumps.

The golfer confronted by the previous dilemma (i.e., having to 'shape' a shot around an obstruction) is also likely to use the pre-performance routine to critically consider the extent to which they must deviate from their normal movement pattern. Although this process might not involve a great deal of arduous deliberation it does require the performer to consider a number of important factors. For example, the golfer might contemplate how the body must 'open up' to the target and align itself in a manner which will encourage the swing plane to move severely from outside-to-in – thereby imparting the desired left-to-right spin on the ball. During the pre-performance routine the golfer might practice adjusting their stance (particularly how their feet are aligned to the target relative to the position of their shoulders) and consider how various alterations to their alignment are likely to influence the desired shape and trajectory of the shot. In this situation, the performer might draw on expproprioceptive feedback – which involves a consideration of the orientation of one's whole body to the surrounding environment. On some occasions the performer might intuitively find the correct stance and little or no conscious deliberation is required. However, the relative novelty associated with this situation will mean that some conscious and deliberate thought is usually required before the golfer is confident that they can successfully execute the stroke.

Golfers might also draw on experiences accrued during practice rounds to help them strategise during the competitive event itself. To illustrate, when planning a tee shot I may recall how the ball reacted when it landed on a specific side of the fairway during the practice round. I can use this memory to inform my choice of stroke and to consider where best to place my tee shot during competition. I might also use practice rounds to establish a feel for the pace, slope and grain (i.e., how the grass lies) on each putting surface and use these memories to help decide how putts might react during competition. Similarly, when recalling his British Open victory in 2004, Todd Hamilton revealed that he "probably watched three or four hours of TV on the last morning which helped a lot. I saw guys putt from certain angles and kept that in the back of my mind" (Hodgetts, 2013). Hamilton noted the speed and break (i.e., how putts were influenced by the slope on a green) of putts on particular greens and used that information when planning and executing his strokes later that day. So even when situations do not call for large-scale alterations of technique, in sports such as golf, performers must adapt to the specific constraints presented by an ever-changing environment (i.e., new course, new pin positions on greens, changing weather conditions) and this means drawing on mental representations to cope with these evolving conditions (Eccles, Ward, & Woodman, 2009).

Cognitive control during on-line skill execution

Thus far we have marshaled evidence which points to the important role conscious deliberation plays during skilled performers' *training regimes* and *pre-performance routines* in the competitive context. Next we will consider the role cognitive control may play during *on-line skill execution*. Although Dreyfus describes on-line skilled performance as proceeding intuitively and without conscious awareness of one's movement, an impressive body of empirical evidence shows that self-awareness is an important mediator of 'flow' or optimal competitive performance in sport. For example, on the basis of their pioneering research on flow in sports, Jackson and Csikszentmihalyi (1999) argued that “without self-awareness an athlete misses important cues that can lead to a positive change in performance” (p. 105). According to these authors, self-awareness involves paying attention to cues provided by movements, and making adjustments to our actions when outcomes are undesirable. Importantly, a number of authors have argued that attending to kinesthetic feedback will provide athletes with cues that they are on track and headed towards their goals (e.g., Breivik, 2013). Further evidence that performers engage in self-awareness during on-line performance comes from research by Baker, Cote and Deakin (2005) and Masters and Ogles (1998) who found that elite long-distance runners monitored their internal states more closely and focus more on planning their race performance during competition than their less accomplished counterparts.

More recently, Hanin and Hanina (2009) reported the optimal focus of attention adopted by an elite 200 metre runner during racing. Results revealed that the athlete focused on acceleration as he left the blocks and maintained an *external* focus (i.e., focusing on the effects of one’s actions on the environment or directing attention away from movement mechanics) by concentrating on a smooth entry into the curve and using the curve effectively by controlling the run with his gaze. Interestingly, the athlete then switched to an *internal* focus of attention (i.e., focusing on the movements of one’s limbs) by‘re-starting’ his engine on the straight and increasing his level of effort to finish the race. The authors point to the fact that this dynamic alteration in attentional focus and flow of thoughts took place in 20 seconds. Relatedly, Nyberg (in press) found that elite freeskiers use their ‘focal awareness’ (which is conscious and includes knowledge of their velocity and how they need to modify it) to such an extent that they “know whether they will be able to perform the trick the way it was intended without adjustments, or whether they will need to make adjustments during the flight phase” (p. 7). Together, the preceding evidence indicates that competitive performance regularly presents the skilled performer with situations which are challenging or relatively novel and that conscious and critical deliberation is essential if these context-specific demands are to be negotiated. These types of behavior are characterized by conscious and deliberate attempts to engage in mindful coping which involve monitoring or altering one’s movement during on-line skill execution in an attempt to maintain performance proficiency.

Moreover, more recent empirical evidence indicates that performers might use kinaesthetic cues as an ‘instructional nudge’ to tone and reshape their grooved routines (see Sutton, 2007) during on-line competitive skill execution. These forms of bodily awareness have been variously described as ‘mood words’ (e.g., see

MacPherson, Collins, & Morriss, 2008), ‘global cue words’ (e.g., see Gucciardi & Dimmock, 2008) and ‘swing thoughts’ (see Jenkins, 2007). These particular forms of conscious attention appear to facilitate performance effectiveness by encouraging “appropriate subactions to be generated implicitly” (Kingston & Hardy, 1997, p. 291). With this in mind, let us consider how the use of ‘swing thoughts’ may influence performance efficiency in golf. Marchant (2008) described a swing thought as representing “the thoughts or images a player uses prior to and during the execution of a shot, and may be seen as the culmination of a golfer’s pre-shot routine” (p. 19). In seeking to establish the prevalence of swing thoughts used by elite golfers Jenkins (2007) interviewed 113 European tour players and found that 70% of these performers used at least one swing thought during on-line performance. For example, Jenkins (2007) quotes one of these players as saying “I think it’s good to have a swing thought for the week. Whether it be smooth takeaway, or grip lightly with the left hand; … it helps you concentrate harder because if you don’t have a swing thought, then you’re just standing up and hitting the ball and I don’t feel that you concentrate one hundred percent” (p. 201). Although these forms of ‘instructional nudges’ might act as a prophylactic against the potentially deleterious consequences of performance pressure they might also prevent the mind from wandering to unwelcome places (e.g., What if I do not make the ‘cut’ in this golf tournament? If I don’t, I might lose my playing rights on tour).

Empirical evidence suggests that these swing keys may be most effective when they are holistic or global in nature (Gucciardi & Dimmock, 2008; Mullen & Hardy, 2010). Indeed, global or ‘holistic’ cue words appear to represent a specific type of cognitive control which can actually facilitate performance effectiveness amongst skilled athletes. These cue words represent a form of mindedness because their adoption requires the performer to be consciously aware of the general feeling of their movement while executing a task (Mullen & Hardy, 2010). Gucciardi and Dimmock (2008) found that the use of a global cue word produced superior performance compared with the use of task-irrelevant cue words or explicit knowledge cue words when experienced golfers (handicap 0-12) performed a putting task under low-anxiety and high-anxiety conditions. In the global cue word condition, participants formulated words which combined the mechanical processes of their putting action such as ‘easy’ and ‘smooth’. In attempting to explain this latter finding, Gucciardi and Dimmock (2008) suggested that the use of the global cue word allows the expert performer to direct “their thoughts, focus their attention and trigger their implicit processes stored in memory” (p. 56). Another potential explanation is that cue words that represent the characteristics of the entire movement are capable of activating sensory motor networks through referential connections. More recently, Mullen and Hardy (2010) examined the effects of part process and holistic goals on the performance of novice and expert athletes in three different sports (athletics, basketball and golf). Results indicated that a single holistic process goal (e.g., smooth, soft) interacted with increased levels of cognitive anxiety to maintain or improve performance efficiency, while a single part process goal (e.g., focus on extending the shooting arm in a basketball free throw task) led to inferior performance.

Collectively, the preceding evidence indicates that expert performers regularly use cognitive control to help shape, guide and improve embodied routines in both the practice and competitive context. Skilled athletes appear to maintain performance proficiency by ensuring that most features of their performance are open to strategic control. Indeed, the evidence presented in the current paper indicates that intuitive and deliberate activity can appear and disappear even during on-line performance at a high skill level (see Breivik, 2007; 2013). Unfortunately, many of the theoretical perspectives which have been used to identify the cognitive mechanisms mediating skilled performance (e.g., Dreyfus & Dreyfus, 1986) lead us to think in dichotomous terms by presenting the performer as engaging in either ‘conscious, deliberate, self-referential action’ or in ‘absorbed coping’ (Breivik, 2007, p. 128). The evidence marshalled in the current paper would suggest that a better understanding of the cognitive processes shaping skill development at the elite level can only be achieved by adopting a theoretical framework which can account for the dynamic nature of attentional processing. We propose that Sutton et al.’s (2011) ‘applying intelligence to the reflexes’ (AIR) approach may help achieve this latter aim.

Briefly, Sutton et al.’s AIR model implies that expert skill relies on a mindedness that “facilitates the dynamic flexibility of attention, allowing it to be allocated freely and in a way that best meets contingent contextual demands” (Geeves, McIlwain, Sutton, & Christensen, 2014, p. 676). According to this perspective, skilled performers must be able to make on-the-fly decisions and can only achieve this by monitoring the processes involved in performance as they unfold. Moreover, the situations faced by experts, in both practice and competitive contexts, have too much variability for them to rely solely on automatic processes. Accordingly, the skilled performer may draw on the reservoir of knowledge stored in long-term working memory to plan and strategise during performance or somaesthetically evaluate the quality of their on-line skill execution and choose to use cue words to groove embodied habits. So, in even the most habitual activities, we “retain significant levels of care, attention, and kinetic awareness” (Sutton et al. 2011, p. 88). It is precisely because experts are used to engaging in mindful activity that they are capable of effectively switching between different modes and styles of attentional processing in both the training and performance context. In addition, the performance context always presents the athlete with novel or threatening situations which require deliberation and, possibly, a critical consideration of how embodied routines must be shaped. Sutton et al. (2011) argue that skilled performers have opened up their ‘reflexes’ into acquired adaptive patterns which might help explain how they are capable of reconstructing ‘attenuated’ movements during practice and transforming action sequences during performance.

Accordingly, the AIR model may help us interpret the accumulating body of empirical evidence which suggests that continuous improvement at the elite level is mediated by mindfulness in both the practice and performance context. By planning, monitoring and adjusting embodied routines, skilled performers actually “resist the kind of automation which Dreyfus ascribes to the highest level of expertise, worrying that trusting the body alone to take over will lead to arrested development” (Sutton et al. 2011, p. 95). At all stages of training and performance, the performer must remain ‘somaesthetically aware’ of their movement as a reliance on spontaneity or intuition alone is unlikely to help the skilled performer deal with the context-sensitive (e.g., changing weather conditions, new venues, the fallibility of habitual movement) demands presented by competitive environments. We see our work as having supported Sutton et al.’s (2011) model by identifying *three* specific mechanisms that appear to underpin cognitive control in skilled performance.

First of all, performers may use ‘*somaesthetic awareness*’ to identify an attenuated movement pattern which they may choose to alter or refine in the practice/performance context. Second, performers may employ heightened attention when they *recognise threat* in the competitive context. For example, practice rounds allow the skilled golfer to become familiar with a new course/venue and help them pinpoint precisely where danger may lie. During competition, the golfer may refer to notes taken during the practice round, or recall the outcome of specific strokes, to help inform strategy and to ensure that unnecessary risks are avoided. Finally, athletes may use *self-regulation* to monitor their attentional focus or to identify any negative cognitions, or inefficient movements, which may have arisen during performance. Consequently, the performer may decide to use cue words as a prophylactic against the potentially deleterious consequences of performance pressure or instructional nudges to reshape some embodied routine.

We hope that the evidence presented in the current paper will encourage researchers to develop more fine-grained conceptualisations of cognitive control in a wide variety of motor skill domains. Researchers might pursue this line of enquiry by seeking to elucidate the mechanisms that underpin detached forms of cognitive control (e.g., those that occur in practice contexts) and those that characterise more immersed modes of control (e.g., those that occur during on-line skill execution). Here, Gallagher and Marcel’s (1999) concept of ‘embedded reflection’ might be usefully applied to an analysis of the latter mode of processing while the concept of ‘introspective reflection’ might help us to explain the mechanisms involved in the former. In addition, although we drew on the concept of ‘detached deliberation’ to explain how athletes may weigh up various options (e.g., risk versus reward associated with a particular action) in the pre-performance context we recognise that alternative explanations of decision-making expertise exist. For example, according to Serfaty, MacMillan, Entin, & Entin’s (1997) three-stage hourglass model of decision making, skilled performers often generate an initial plan on the basis of recognition of the nature of the situation (where an option is chosen quickly and with little deliberation) and subsequently devote cognitive resources to considering different methods of executing the skill. Future research might help us gain a better understanding of this latter process by exploring the relationship between temporal constraints on action and the modes of cognition used by experts when making decisions. In a similar vein, we hope to investigate the various types of cognitive control that skilled performers may engage in during competitive performance and explain why some might harm skilled performance and why others may enhance it. Finally, from a methodological perspective, it is important to acknowledge that much of the evidence presented in the current paper is based on athletes’ phenomenological accounts and that some researchers have questioned whether performers are capable of providing accurate reports of their cognitive processes (Abernethy, Burgess-Limerick, & Parks, 1994). Researchers may wish to address this issue by using a variety of process-tracing measures (e.g., eye-tracking technology) in order to corroborate these phenomenological insights.

Skilled performance, we have argued, far from being the paradigm of nonmindedness, as Dreyfus seems to think, appears to be imbued with mindful activity. Like Sutton (2007), we question whether “expertise is so completely cut off from conscious or articulable influence” (p. 768) and argue that cognitive control plays a key role in facilitating ‘continuous improvement’ at the elite level of sport. In supporting this argument, we have outlined evidence which shows that experts can use thought and personal memory to shape and guide grooved habitual performance during both training and competition. Experts are neither zombies who mindlessly work their way through their world of action, nor computer-like devices that only process information according to certain programs or rule structures (Moe, 2005). The AIR approach provides a useful bridge between these two dichotomies by portraying expert skill as a combination of top-down, overarching, cognitive hierarchical structures and bottom-up, embodied feeling and action. Which actions are benefited by deliberation? This in part depends on which actions an expert has been practicing in a thoughtful deliberative way. And it also depends on which actions allow time for deliberation. Certainly a marathon permits time for thought, however, we posit that a wide variety of activities that one might naturally think of happening extremely quickly actually permit time for conscious control. Indeed, since, as Thomas Hobbes tells us in the Leviathan, “thought is quick”, we hypothesize that almost every form of expert endeavour—everything from race car driving to playing lighting chess to even swinging a golf club—allows for and can perhaps be benefited by some form of deliberation.

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