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BREADTH AND DEPTH OF KNOWLEDGE IN EXPERT VERSUS NOVICE ATHLETES

John Sutton and Doris J. F. McIlwain

Knowledge and sport expertise

Questions about knowledge in expert sport are not only of applied significance: they also take us to the heart of foundational and heavily disputed issues in the cognitive sciences. To a first (rough and far from uncontroversial) approximation, we can think of expert "knowledge" as whatever it is that grounds or is applied in (more or less) effective decision-making, especially when in a competitive situation a performer follows one course of action out of a range of possibilities. In these research areas, studies of motor expertise have for many years actively contributed to broader debates in philosophy and psychology (Abernethy *et al.*, 1994; Williams *et al.*, 1999). When we navigate the world flexibly and more or less successfully, how much is this due to a capacity to *represent* it? In considering alternative options, or planning future actions, we seem to transcend our present environment in some way: what is the balance or relation here between highly tuned bodily dispositions and background *knowledge* of the world and its patterns? What changes in these regards as we gain experience and adapt to more complex and challenging environments? Is know-how fundamentally different in kind from ordinary factual knowledge of the world, or knowledge-that? And if expertise in a domain does involve or depend on a knowledge base that is somehow more organized or deeper than that of novices, how is this knowledge selectively and appropriately deployed, often under severe time constraints?

The complex, highly structured, culturally embedded worlds of elite sport afford extraordinary opportunities for cognitive scientists to study the mind in action. Experts voluntarily dedicate years to arduous self-transformation, integrating their perceptual, cognitive, and motor capacities with respect to their chosen domain in ways that may be entirely different from most participants in psychological or cognitive neuroscientific experiments. At this stage of science, at least for the kind of questions we listed above, we suspect that sport still has more to offer cognitive theory than vice versa. There is as yet no general theory of the varieties of human knowledge and the roles they may play in skillful actions of any kind that can simply be applied to the sport domain. However, such theories must be tested against the unique features of expert performance in the natural ecologies of sport.

The tasks posed in professional sport are extremely diverse, and both the role and the application of expert knowledge will likely vary widely. This is true, first, across individuals: within the same sport, and even at similar levels, significant variability across performers is often due as much, if not more, to differences in cognitive style – in players' characteristic patterns of options taken and tactical decisions made – as to distinct physical or technical skills. Second, the situational constraints of different sport scenarios shape what knowledge may be relevant and how it may be used. So researchers should not rush to find a single general theory of expert knowledge in sport, for there may be genuine differences across settings in what experts know and how they deploy that knowledge. In this chapter we have in mind, for the most part, more open sporting environments in which the situation and demands can change rapidly, and the expert must respond to more or less unpredictable events in either team or individual contexts. While the distinction is not absolute, the contrast is with more closed sports in which the performer initiates movement herself, more independently of the task environment, and – in some cases – aims primarily to reproduce a sequence of actions, rather than having to adapt on the fly to dynamic events around her. Think of soccer, with its more or less continuous motion, as opposed to many forms of gymnastic routine, or the rapidly changing passages of play in a long tennis rally, in which the players' movements and decisions sometimes seem to be interactively, dynamically coupled, as opposed to competitive diving. Expert knowledge in more closed sporting contexts may take different forms.

In complex open sports, reliance on knowledge is often treated with some suspicion by elite athletes and coaches, and ambivalent attitudes to expert knowledge are also apparent in the theories we discuss in this chapter. The concept of "knowledge" is seen by some as overly static, as referring to internal psychological structures that seem too rigid to explain fast decision-making and action in sport. In some contexts, expert practitioners' lore privileges heavily practiced, embodied movement skills over any residual cognitive representation, and intuitive decision-making on the basis of vast experience over any deliberate or thoughtful use of background knowledge. As we will see, some leading psychological theories in sport science take a similar view. In the next section, we discuss existing taxonomies of kinds of knowledge. But in practice too the terms "knowledge" and "thinking" arguably have a range of distinct meanings. We can illustrate this with an anecdote. At the 2010 Cricket Australia conference on science, medicine, and coaching in cricket, two successful and reflective elite coaches, who were also close collaborators, spoke in succeeding sessions. In a panel on the increasing need for cricket batters to adapt both to new forms of the game and to more rapidly changing situations on the field, one ex-elite player and coach noted, "as we all know, the best batters are the best thinkers." Within minutes, in the following session, his colleague was saying, "as soon as a batter starts *thinking*, you know he's in trouble." As we will suggest, both perspectives make sense once we clarify the terms. *Over*thinking your game is widely demonized in elite sport: it may be seen as anxious worrying, or as excessive focus on aspects of the mechanics of performance which may be useful in practice, but in competition should be left to grooved, embodied routines. There are clear bases for these beliefs: in some circumstances, monitoring the components of one's actions, or trying to impose cognitive control over lower level movement steps, disrupts an effectively chunked, smoothly unfolding, practiced skill. But we can also make sense of the alternative conception of thinking, by which leading athletes do sometimes draw *directly* on a rich, organized, and sophisticated knowledge base in order to respond appropriately to highly dynamic environmental and performance demands.

Before working through a range of theories about the nature and use of knowledge in expert sport, we underline certain general features of skilled performance at the highest levels. Elite athletes commonly face new challenges and unexpected forms of pressure. There are no simple repetitions in sport. Even when an expert faces familiar opposition in the same location on a different occasion, much of relevance may have shifted: confidence, fitness, rankings, recent technical issues, competition stage, mood, weather, motivation, and other contextual factors are rarely identical. So performers must constantly take themselves further, going beyond their particular past experience. Their repertoires of embodied skill are flexible, so they can adapt effectively to new opponents or teammates, unpredictable or unfriendly environments, and the constantly monitored state of their body. They value the ability to *generalize* skills to increasingly challenging conditions, and often structure training regimes around preparing to cope outside their "comfort zone." Such variability is to be expected: challenging, more or less unfamiliar conditions are just part of the deal at elite levels of performance. For sure, not every athlete is equally adaptable, equally able to reorient online, on-the-fly performance by "thinking on her feet." In most sports, there are many routes to, and styles of, excellence. But those with exceptional tactical skills who can extend themselves, who rapidly pick up and respond to new circumstances may receive different levels of recognition, perhaps as "students of the game" (McPherson, 2008, p. 155). The basis of such adaptability is uncertain, and nothing we have said so far suggests that it must involve unusual forms of knowledge. But sport science has to respect these phenomena of expert performance, and in particular offer clear accounts of how empirical results gained in more controlled settings might link to or explain such features of the competitive environment. In this chapter we first discuss the distinct kinds of knowledge, which might be important for expert performance, before examining particular attempts to tap sophisticated sport-specific knowledge.

Kinds of knowledge in expert sport

In his excellent sport psychology textbook, Aidan Moran begins a discussion of expert-novice differences by stating, "experts have a more extensive knowledge-base of sport-specific information . . . [they] *know more* about their specialist domains than do relative novices" (2004, p. 178). We observe experts performing better than novices across a range of scenarios: their perceptual systems are exquisitely attuned to subtle cues, and as they effectively anticipate what is coming next their actions are already taking shape. Researchers who focus on expert knowledge argue that it drives this rich integration of perception and action. Experts' perceptual skills are informed by what they know, as certain combinations of sensory stimuli, and not others, appear salient. A vast and unique body of experience shapes each elite performer's knowledge base, which helps her to filter and select relevant, current input and ignore everything irrelevant, and which is in turn constantly updated as new events transpire. Studies of perceptual anticipation and skill in sport are often described as addressing "perceptual-cognitive" expertise (MacMahon & McPherson, 2009; Roca *et al.*, 2013), as researchers acknowledge the *intelligence* built into expert perception.

Terminology in this area can be confusing, and the utility of the term "knowledge" in this context is not secure: a richer vocabulary would be welcome. Most theorists refer to a standard taxonomy in cognitive science by which "declarative knowledge" is distinguished from "procedural knowledge." Roughly, declarative knowledge is knowledge of facts, whereas procedural knowledge is knowledge of how to act. The uses of these terms, however, are far from consistent, and these concepts should not be presented as if there is a clear scientific consensus. Before we discuss each in turn, we note the direct relevance of parallel debates about knowing-how and knowing-that. Gilbert Ryle argued powerfully in *The Concept of Mind* (1949) that knowing how to do something is prior to, and independent of, knowledge of any set of facts, attacking what he called the "intellectualist" view that knowing how to do something simply consists in knowledge of certain facts. This is a live and controversial issue in contemporary philosophy (Fantl, 2012; Gascoigne & Thornton, 2013; Stanley & Krakauer, 2013). Although this literature has potentially rich connections to the study of knowledge in sport expertise, the mere existence of a distinction in cognitive science between declarative and procedural knowledge does not confirm that Ryle was right (Devitt, 2011). Neither the nature of procedural knowledge nor the relation between the two is settled in such a way as to decide this issue, and perhaps the terms are still best thought of as broadly descriptive labels rather than well-defined explanatory or natural kind terms.

To a first approximation, then, declarative knowledge of facts is explicit and can in principle be consciously accessed. The category includes not only semantic knowledge of both general and specific information (about the typical nature of a sporting venue, for example, or about an opponent's recent results), but also episodic memory, such as an expert's recall of her last game against the opponent (Sutton, 2007; Sutton & Williamson, 2014). Two connected preliminary points are needed here. First, this use of "knowledge" does not entail that experts' "knowledge" is *all* true or accurate. In philosophy and in many ordinary contexts it would be more natural to say that they have certain *beliefs* about the world, or *model* the world in such and such a way: people may – and often do – *believe* things that are not true, but in ordinary language we cannot *know* something that is not true. As Moran's term "knowledge base" suggests, the relevant notion here is more liberal and inclusive: the sport expert's "knowledge" is a complex, heterogeneous, dynamic body of information, which may fit more or less neatly with reality. Second, someone knows many things he is not currently thinking about: e.g., John knew the result of the Melbourne Ashes test of 1982–83 before he thought about it again just now, and indeed he has known it for years. So knowledge, like belief, can take a dispositional form, when someone is disposed to act appropriately on the basis of knowledge if prompted, as well as an occurrent form, when she exercises that knowledge now.

Talking of declarative knowledge as explicit knowledge of facts, in the standard way we have so far, can easily be taken to suggest either that declarative knowledge is itself linguistic in form, or at least that it is essentially verbalizable. Although verbal reports are a vital source of evidence, as we discuss further below and in the associated chapter on methods for studying expert knowledge (see Chapter 20), declarative knowledge should not be *defined* as reportable. The representational media of declarative knowledge may be entirely non-linguistic in form. As well as the possibility of sensory, imagistic, or kinesthetic forms of representation, cognitive psychologists use terms like "schemas" and "situation models" to describe dynamically updated ways in which experts richly map their domain, and there is no reason to assume that the content of such mental models can be easily or accurately translated into verbal form. Not everything that is consciously accessible is thereby also verbally articulable: an expert can know or accurately map certain features of the world, as revealed for example in successful action, without necessarily being able to *explain* what she knows.

In the case of sport, of course, what the expert "knows" may be not only inarticulable, but also not accessible at all. On many views, at least parts of the knowledge base may operate at a subpersonal level: experts need not be aware, for example, of the knowledge which guides their eye movements so as to pick up information from only the relevant parts of the perceptual scene. This is then, on most views, part of procedural rather than declarative knowledge. Given this very rough sense of the distinction, and smoothing over finer-grained theoretical issues, we can characterize three broad approaches to knowledge in sport expertise. The strongest views are those on which the expert makes significant use of declarative as well as procedural knowledge in action, where the interaction between the two can take a range of distinctive forms: we discuss approaches of this kind in the following section. Here, first, we briefly look at the other two general options. Some argue that procedural knowledge is the core of the expert advantage, with declarative knowledge being either irrelevant or an actively disruptive force, while others suggest that experts are not drawing substantially on *knowledge* at all.

First, in approaches based on general theories of expertise like that of Anderson (1982), procedural knowledge is seen as a system of "if-then" production rules or recipes for motor

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performance: for McPherson and Thomas, this aspect of sport knowledge includes "patterns or rules for generating patterns of actions to produce goal related changes in the context of a game situation" (1989, p. 192), thus linking conditions to actions. On such views, procedural knowledge is not profoundly different in *kind* from declarative knowledge, but merely has different contents and – most importantly – different modes of application. Indeed, on most such views, deriving originally from Fitts and Posner (1967) as well as Anderson (1982), knowledge of a relevant domain is first declarative in form, but then with experience becomes "proceduralized" such that its deployment in experts is automatic and unconscious. In the transition to expertise, items of knowledge that were originally distinct are linked or compiled, so that the number of individual variables to be retrieved is reduced: likewise, actions that tend to follow each other are composed into linked or chunked sequences.

On these views, once the expert's knowledge is thoroughly proceduralized, action production becomes automated and independent of cognitive control. Neither explicit knowledge nor explicit memory is required in driving expert performance, and in turn on this view no rich episodic memories of performance will be encoded and retained. Effective responses to perceptual input are both faster and more effortless for experts because their actions are "controlled in real time by procedural knowledge that requires little attention, operates largely outside of working memory, and is substantially closed to introspection" (Beilock & Carr, 2001, p. 702). Experts may well also have more "extensive and systematic" explicit general knowledge about their domain than do novices, but this is not the essence of their skill advantage. Such declarative knowledge, indeed, should, if these views are correct, operate only "offline" rather than during performance. For experts, the *online* control of action by declarative rather than procedural knowledge is detrimental to performance, breaking up the uninterrupted units of the proceduralized control structures, leading to an unwanted focus on the component parts of the motor process: Masters and Maxwell (2008), for example, argue that when experts consciously reinvest declarative knowledge from an earlier stage of their training, performance will regress. Many current theories of choking in elite sport explain severe breakdown under pressure on this basis, as resulting from inappropriate self-monitoring or attention to motor execution when experts suffer "paralysis by analysis" (Baumeister, 1984; Masters, 1992; Beilock & Gray, 2007; see also Christensen *et al.*, in press).

Whereas on these accounts procedural knowledge drives expert sport performance in real time in smooth and effortless ways that declarative knowledge cannot, more radical are claims that knowledge is not directly involved at all. For Araújo and colleagues, "the distinction between declarative and procedural knowledge is elusive, since both types of knowledge are verbal formulations" (2010, p. 1088). This may not be quite the right way to put the worry, since the representational resources in question are not meant to be linguistic in form or exhausted by verbal output. But the alternative claim is that expert performance is best characterized as the ability or skill to perform certain actions: it is to be explained *simply* on the basis of such embodied capacities or dispositions, such that the element of "knowledge," understood as a representational system or model independent of the current environment, drops out of consideration. There are both constructive and critical strands to these lines of thought. An extensive body of theory and empirical research in ecological dynamics has, as described elsewhere in this handbook (see Chapter 12 for example), shown how specific regularities in the environment richly shape and constrain the opportunities for action. When there are organisms in that environment which are appropriately attuned in that they have developed "the functional capacity to pick up relevant information to guide actions" (Araújo & Davids, 2011, p. 14), the environment "is perceived directly in terms of what an organism can do . . . not dependent on a perceiver's expectations, nor mental representations linked to specific performance solutions, stored in memory" (Silva *et al.*, 2013, p. 767). Following J. J. Gibson, ecological sport psychologists deny that *knowledge* *about* the task domain, in the form of representational schemas or organized expert memory structures, is the core of expert skill. Instead, the expert does have *knowledge of* the environment, but this is simply "the ability to complete an action by detecting the surrounding informational constraints in order to regulate behaviors" (Silva *et al.*, 2013, p. 767).

So for these theorists, no specialist knowledge or expert memory is *acquired* in skill acquisition: the idea that expert advantages must be due to enriched or better organized information in a knowledge base is seen as a residue of classical cognitivist theory which does not apply in the domain of sport and movement (compare Dreyfus, 2002). Perception and action are coupled without mediation, so there is no central role for knowledge or cognition (Chemero, 2009). Part of the point here is that the moving, embodied organism is active in an information-rich environment, so that perception and action are fundamentally situated (Clark, 1997; Robbins & Aydede, 2009): "the skilled regulation of action is actually distributed over the organism-environment system" (Araújo & Davids, 2011, p. 14). But ecological theorists add that the increasing attunement or calibration of the expert performer to the available environmental information is a primitive biological or dynamical consequence of task experience which must not be cashed out in terms of "increasing amounts of knowledge in memory or more sophisticated movement representations" (Araújo & Davids, 2011, p. 10).

Again, this debate about sport expertise mirrors and runs alongside long-standing and difficult controversies in the cognitive sciences at large. If densely interconnected natural and cognitive ecologies heavily constrain action opportunities, are the unique and context-sensitive options taken by skilled performers on particular occasions fully explained in terms of attunement, embodied disposition, and intuitive response? Is there a middle-ground position between these knowledge-free theories and the more classical information-processing models, which have often seemed too rigid and slow to account for dynamic expert performance? This is the challenge for sport researchers who retain a role for knowledge in their accounts of expertise. Is there a kind of knowledge that is less like a clunky set of internalized propositions, and that could explain the dynamics of interactive movement in high-speed, expert sport? Versions of the classical frame problem for artificial intelligence threaten here (Wheeler, 2008). If the knowledge base is as rich and full as seems necessary to explain the range of expert skill, how can it be searched effectively at speed? How do the lessons of new experience generalize rapidly, without explicit attention to each possible context? How can certain recipes be updated on the fly during performance while others are untouched? In the following section, we show how some theorists of expert knowledge seek to address the paradox that experts must have much more knowledge to search through than novices, but seem to be able to retrieve and act on it faster and with less effort than novices (Moran, 2004).

Approaches to expert knowledge in sport

The two approaches we discuss in this section draw in different ways on the same theoretical framework to suggest how experts meet this challenge and access distinctive memory systems in performance. Experts work around the usual capacity limits of long-term memory by chunking specialist knowledge in rich and organized forms, and by developing fine-grained retrieval structures that permit rapid, controlled access to knowledge, which can then play a dynamic role in the control of ongoing action (Ericsson & Kintsch, 1995). This long-term working memory theory (LTWM) has been applied in many domains of expertise research. It is not the only relevant theory, and there remain many questions about the theoretical details and commitments, but it has proved productive in driving work on sport expertise (Ward *et al.*, 2013).

In a sustained research program, Sue McPherson and colleagues have sought to tap expert knowledge by asking players across a range of sports to report their thoughts during competition, with reference to what has just occurred or to their immediate plans. Elite tennis players, for example, are asked between points what they were thinking about while playing the last point, or simply what they are thinking about now. The use of verbal report data raises methodological issues (see Chapter 20), but such "think-aloud" protocols, involving immediate retrospective reporting, are the most promising way to explore the breadth, depth, and diversity of the knowledge base (Ericsson, 2006; Eccles, 2012). The idea is not that reported thoughts are themselves "blueprints for motor performance," but that they "play an integral role in determining players' response selections" (French & McPherson, 1999, p. 180). Consistent patterns of difference in expert and novice knowledge have been found across sports including tennis, baseball, volleyball, and basketball.

First, McPherson and colleagues find microlevel differences in what experts attend to during competition. While novices and less-experienced players often attend "to irrelevant conditions in the current environment" (French & McPherson, 1999, p. 185), experts are thinking in more thorough, more varied, and more fine-grained terms about current conditions – such as their opponent's strengths or weaknesses – and about specific actions and responses (McPherson, 1994, 1999, 2000). Where novices tend to think in terms of a general goal of winning, experts generate more detailed planning concepts. In a landmark study of baseball players' thoughts as they prepare to bat against a particular pitcher, for example, McPherson and MacMahon (2008) found that stronger players quickly develop an extensive profile of the pitcher's strengths and preferences, which allows them to generate detailed predictions about a specific upcoming pitch.

Next, McPherson identifies two key, larger-scale memory structures. Experts develop action plan profiles, which link conditions to possible responses. In contrast, while less experienced baseball players may have some general baseball knowledge, they find it harder to connect to the actual circumstances of a game situation: several younger players, in another study, "continuously rehearsed the same plan prior to every pitch" (French & McPherson, 2004, p. 417). Further, experts have elaborate current event profiles that keep track of active relevant information: these tactical scripts include updates on a current opponent, conditions, and other contextual factors, and can guide adjustments to performance during competition. Expectations can be both highly specific and constantly modified. Crucially, experts can use these current event profiles to monitor and interpret shot selections and tactics, guiding the modification of performance in real time. Verbal labels or maxims attach to knowledge structures with a definite history, so that the expert can use them to interpret specific movement problems. This capacity to use information derived from particular prior experience is striking: whereas an expert monitored how the present situation relates to his own past performance and that of his opponent, novices "did not access past events or information from previous competitions" (French & McPherson, 2004, p. 418).

McPherson's studies have both applied and theoretical implications. In contrast to the idea that any explicit thinking may disrupt embodied performance, these results lead her to "advocate that players periodically record their thoughts during competition" (McPherson & Kernodle, 2003, p. 162). The knowledge structures identified in this research are, as McPherson and colleagues see it, the key means by which experts precisely identify the immediate problems facing them. Of course, a range of other factors underlies response selection, including those responsible for perceptual anticipation and action execution. But, as MacMahon and McPherson state forthrightly, the knowledge base is the "driving mechanism which influences component behavior:" this is, as they acknowledge, "a more hierarchical view . . . with knowledge base as the driver" (2009, p. 571–2). Reports of thought processes can thus be integrated with other process tracing measures such as eye movements.

This is exactly the approach taken in another line of mixed-method research by Ward, McRobert, and colleagues. The well-established expert advantages in perceptual anticipation, such that experts attend to relevant advance cues and can predict the time course of events earlier and more accurately, are not isolated from cognition, but spring from and, in turn, test and update the experts' elaborated knowledge. Their underlying representations of the specialist domain in long-term working memory "provide a dual function: they provide memory support for performance, in the form of planning, monitoring and evaluations, while simultaneously enabling retrieval structures to be built and updated 'on the fly' that promote direct access to task pertinent options" (McRobert *et al.*, 2009, p. 475). In a series of experiments using simulated, video-based task environments, in sports including cricket and football, these researchers integrate study of expert eye movement with analysis of verbal report data gathered immediately after specific responses.

Employing a related scheme for coding experts' verbal reports of their thought processes, four major types of cognitive statement categories are distinguished: *monitoring* of current actions and descriptions of current events, *evaluations* and assessments or appraisals of relevant events, *predictions* which anticipate what might occur next or in future, and *planning* statements identifying possible decisions or looking for alternatives beyond the next response (Roca *et al.*, 2011, 2013). Across a series of studies, experts are found to discuss more task-relevant options whereas novices think about more irrelevant options (Ward *et al.*, 2013); experts engage in more prediction and more planning than less-skilled performers, and in some settings also deploy more evaluative statements (McRobert *et al.*, 2011). In football, for example, Ward and colleagues (2013) conclude that experts are "dynamically encoding and integrating the evolving pattern of play on the fly, apprehending and representing each possible threat posed by the opposing team hierarchically, while excluding from their situation model the opposing players who did not pose a threat" (2013, p. 250). Likewise, in a cricket batting task, expertise involved "the development and constant update of elaborate knowledge representations that guide input and retrieval of pertinent information from the visual scene and from long-term memory in an integrated manner" (McRobert *et al.*, 2011, p. 532).

By manipulating the amount of relevant contextual information available, McRobert and colleagues could also assess the way experts integrate recent history into their ongoing knowledge and assessment of a situation so as to better predict the likely sequence of events. They presented the same test stimuli – video of balls bowled by the same cricket bowlers – either in actual sequence as performed, replicating match conditions, or embedded in a random sequence of deliveries from six different bowlers. In the former, high-context condition, expert batters' eye movements differed in that their fixations were of reduced duration, as a result of the cumulative information available about the particular bowler. Further, in this high-context condition batters' verbal reports included more evaluation and planning statements than in the low-context condition (McRobert *et al.*, 2011). Such experimental study of the way that recent context interacts with longer-term knowledge is a particularly promising avenue for assessing what is likely a central contributing factor in experts' performance advantage in competitive settings.

Further challenges for the study of breadth and depth of knowledge

We conclude with three brief suggestions about natural extensions of the lines of enquiry described so far, in turn addressing methods, knowledge in relation to other aspects of expert psychology, and knowledge in teams. As we gain increasingly sophisticated and realistic methods for the experimental study of expertise, we can also afford to extend the ways we seek to tap expert knowledge in the wild, in the complex and culturally embedded settings where experts actually train, swap notes, and perform. This means in part the wider range of qualitative methods for analyzing expert talk and thought, as discussed in our companion chapter on methods (see Chapter 20). However, because the kind of tacit knowledge which characterizes expert performance

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is not easily achieved and not easily communicated, it also suggests integrating empirical sport science more with ethnographic research. We can learn to listen better to what elite athletes say to each other and to their coaches and support staff. These are obviously not direct lines into the springs of action, but equally the terms which experts have developed for communicating and renegotiating aspects of skilled performance are not likely to be wholly confabulatory. Talk about embodied skills can be analogical and indirect, with groups of experts often evolving local responses to the challenges of languaging experience, often "beyond the easy flow of everyday speech" (Sheets-Johnstone, 2009, p. 336). Ethnographic work in these fields often takes the form of participant involvement, as the researcher becomes enculturated into a cultural and physical setting which transforms their bodies, perceptual-cognitive systems, and understanding of the world: examples include work on boxing (Wacquant, 2003), capoeira (Downey, 2005), martial arts (Samudra, 2008), mountain bike racing (Bicknell, 2010), and yoga (McIlwain & Sutton, 2014). Sport psychologists could potentially benefit from attempting the kind of longer-term immersion in the specific culture of expert practitioners at which anthropologists have excelled.

Second, to counter the concern that invocations of "knowledge" isolate or reify an inner realm of mental representations cut off from the rest of the expert's embodied psychology, the rich links between cognition and emotion should be further highlighted in research on expert knowledge. In some cases, emotional knowledge relating to one's own states is itself likely to be better organized in experienced athletes; in other cases, styles of emotion-regulation and emotion-management in performance will partly depend on a sophisticated understanding of the task domain. McPherson's studies again include suggestive results on these topics. Concurrent and immediate retrospective verbal data from less-skilled players include more general emotional reactions to events during play, whereas discussion among experts tended to direct such thoughts into either tactical plans or motivational comments, often linked to potential cues for concentration (French & McPherson, 1999). In some contexts, experts will likely be able to learn more from their own emotional processes, so our methods need to be able to examine the relations between knowledge and emotion.

Finally, alongside and in conjunction with the study of knowledge in individual sport experts, we would like to better understand the roles of knowledge in expert team performance. Some information-processing perspectives on shared knowledge focus on the coordination of explicit knowledge across team members (Reimer *et al.*, 2006), whereas in contrast dynamical and ecological approaches reject talk of shared knowledge in favor of shared affordances (Silva *et al.*, 2013). But emergent knowledge in successful and experienced teams must be more than the mere aggregation of explicit knowledge across the individual members. In many team sports, individuals have dramatically distinct roles and are unlikely to share much or all unique, first-order knowledge that is specific to a particular role. Yet in an effective team, a higher order, transactive memory system is in place such that team members more or less share an understanding of how that knowledge and expertise is distributed within the group. The mechanisms of communication within the group must be highly diverse. More implicit forms of alignment and interpersonal interaction, including various practiced means of non-verbal communication, complement more explicit modes of collaboration in expert teams (Eccles & Tenenbaum, 2004; Williamson & Cox, 2014; Williamson & Sutton, 2014). The study of knowledge in expert teams is one of a range of fascinating areas for research on breadth and depth of knowledge.

Acknowledgments

Our special thanks to the editors. We are also grateful to Kath Bicknell, Clare MacMahon, and David Mann for assistance. Our thinking on these topics owes much to our long-term collaborators Wayne Christensen and Andrew Geeves.

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