

## **Embodied Experience in the Cognitive Ecologies of Skilled Performance**

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### Embodied Experience in the Cognitive Ecologies of Skilled Performance

The skilled performance of experts in complex, culturally-significant settings often involves navigating dynamic, unpredictable circumstances. In elite sport, professional athletes deal with weather conditions, unfamiliar locations or deteriorating conditions, equipment and new technologies, fatigue, pain and risk, audience expectations and noise, the constraints of collaboration, the actions of other competitors, and strong personal emotions. We set a new agenda for research on skill and expertise, to focus on the embodied experience of real expert performers in real domains of practice, as they deploy richly embedded strategies in full and challenging ecological settings. Studying experts' embodied experience, both over time and at a time, requires expanding standard sources for skill theory, to tap not only specialist work in sport psychology, music cognition, and other rich bodies of applied research, but also practitioners' own fallible but unique self-understandings. We address standard concerns about self-report, surveying related methods from cognitive psychology, sport science, and cognitive ethnography, and home in on apprenticeship methods and work by researcher-practitioners. We conclude with an extended case study of professional cyclist Chloe Hosking's account of the closing stages of her winning ride in the 2016 La Course by Le Tour de France, at the time the highest profile event in women's road cycling. Triangulating Hosking's narrative against other evidence, we identify the multiplicity of diverse cues to which she was responding in on-the-fly decision-making. We can learn much about skill and expertise if we work with real experts in the environments to which they are so intelligently attuned.

### **Real experts**

Research on expert skills is harder than studying particular cognitive processes – remembering, hearing, grieving, and so on – because its domain is less neatly bounded. Skill and expertise are multi-level, composite phenomena: multi-level in that they involve neural, cognitive, affective, motor, social, technological, and cultural processes and resources all at once, composite in that expert musicians or sportspeople are deploying many integrated psychological, bodily, and social capacities all at once, from perception and attention through emotion and memory to precise movement coordination and interactive communication.

In a provocative paper for the new *Journal of Expertise*, Fernand Gobet laments that 'the current state of research into expertise is problematic as knowledge is currently fragmented and communication between disciplines is poor'. This is 'regrettable, as many contradictions between the disciplines have been ignored and many opportunities for cross-fertilization missed' (2018: 1, 5).

We embrace Gobet's challenge: 'the way forward for the field of expertise is to join forces and carry out multi-disciplinary research' (2018: 5). We highlight skill phenomena much discussed by expert practitioners, specialist applied researchers, and philosophers influenced by phenomenology and ethnography, which have received less attention in cognitive neuroscience and philosophy of mind. We focus on a) the embodied experience of b) real expert performers in c) real domains of practice, as they deploy d) richly embedded strategies in e) full and challenging ecological settings.

This should not be a surprising ‘turn’ in the field: while there are many reasonable ways to study skill, one useful path is to find, track, closely observe, and listen to experts. This is a natural route to striking case studies, new puzzles, suggestive angles on existing questions, mature empirical traditions, and rich bodies of theory. While here we take the arts and, primarily, sport as our core domains, this kind of naturalistic or natural philosophy of expertise also operates in other fields, from medical diagnosis and surgery to emergency response, from aviation to software engineering, from teaching to science. These fields have long been investigated empirically, from controlled experiment to immersed ethnography. We can tap and critically engage with research on such experts not only in cognitive psychology and neuroscience, not only in the social sciences, but also in the applied sciences of each domain – music, sport, or organisational psychology of various stripes – which integrate distinct levels of analysis, to inform and assist the professions and practitioners themselves.

We focus on experts, those who devote significant time and effort to ‘deliberate practice of their skill, which is practice with the specific aim of improving, and [are] still intent on improving’ (Montero 2016, 10). In some domains, objective or intersubjective standards serve to compare or rank experts; in others, social or reputational factors influence attributions of expertise alongside performance history (Goldman 2018). In other contexts, we argue for more continuity than Montero between everyday and elite skill (Christensen, Sutton, & McIlwain 2016; Christensen, Sutton, & Bicknell 2019): but the features of skill we address show up more clearly in looking at higher or extraordinary, rather than ordinary or dysfunctional, levels of performance.

We consider the embodied experience of experts in skilled performance domains such as sport and the arts in two compatible ways – over time, and at a time. Experts are, as we say, *experienced* performers who hone their skills *over time*, through long and arduous training regimes which directly alter and shape their bodies, tuning perceptual, cognitive, emotion-regulation, and motor capacities which continue to improve and knit together in action. Alongside physical and technical development, experts develop effective strategies for shaping mood and motivation, for detecting salient changes in the environment or in an opponent’s response repertoire, and for building problem-solving capacities to help recovery from trouble. In this sense, the embodied experience of experts is their history of practice. They then deploy their skills *at a time* in performance, and we can enquire into the nature of their experience in doing so. Research on skill and expertise can fruitfully address these two – diachronic and synchronic – aspects of embodied experience together.

Some researchers deliberately avoid the complex and messy contexts of expert action, abstracting away from the ecologies of performance, to focus on single or general features of skill. In different ways, this is true both of the conceptual methods characteristic of philosophical work on know-how (Stanley 2011), and in the isolation of controllable variables for laboratory experiments on the neuroscience of expertise (Bilalić and Campitelli 2018). Such mainstream approaches play important, if rather disconnected, roles in the multi-disciplinary field. But given how little we really know about the nature, components, and bases of skill, it also makes sense to seek more in-situ access to what happens when all the integrated features of expert performance are operating together.

The ongoing rebirth of skill as a central topic in philosophy should be informed by close examination of experts’ embodied experience in the cognitive ecologies of skilled performance. There are a number of ways to do this effectively, and we survey methods for tapping experts’ experience, from more tightly controlled procedures for self-report which deliberately exclude background knowledge and personal insight, to practitioner-driven research and qualitative case studies drawing on participation, interviews, or materials generated by athletes. We hope to encourage an expansion of standard sources for skill research, to incorporate attention to the embodied experience of real experts in uneven and heterogeneous ecologies of practice. In an extended case study from elite

road cycling, with which we end, we show that athletes can tell us much about their successful decision-making in dynamic environments. We triangulate one competitor's reports against a diverse range of sources to suggest how rich and flexible experts' speedy thoughts and feelings can be in dynamic decision environments.

### **Research on embodied expertise**

Expertise researchers have long grasped opportunities to study embodied skills in their natural or home communities and settings. Even historians, for whom musical or other skilled performances are distant in time, address challenges posed by the ephemeral nature of skilled action to analyse particular historical forms of 'kinesic intelligence' (Le Guin 2006; Tribble 2017; Pearlman, MacKay, & Sutton 2018). For contemporary skilled practices, the multi-disciplinary research which Gobet recommends needs to stretch from biology and neuroscience to the sociology and politics of expertise. Integrating such disparate research enterprises, philosophers of cognition, mind, and action can create important niches in multi-disciplinary applied sciences of skill. The last 30 years of cognitive theory have highlighted enactive and phenomenological, ecological and dynamical, embodied and distributed perspectives on cognition and action which align closely with applied concerns. '4E cognition' (Newen, de Bruin, & Gallagher 2018) is changing relations with applied skill domains: we focus again on sport, though similar accounts hold for music, dance, and performance research.

Many philosophers in the 1990s, picking up on and contributing to internal developments in the cognitive sciences, rejected a picture of cognition as an inner process 'sandwiched' between information pick-up and behavioural output. In making the alternative case that flexible intelligent action involves continuous coupling of perception and action, with mutually modulatory dynamics operating between brain, body and world, some introduced analogies with jazz improvisation, sport, and circus performance (Clark 1997, 165; Hurley 1998, 2).

Nonetheless, suggestions that many aspects of embodied mental life might be better modelled on dynamic, improvisatory, collaborative forms of active expertise than on isolated rational deliberation were developed only in general terms, without sustained attention to these domains of practice. Little engagement with applied research took philosophers of mind beyond casual anecdote. The instructive book *Visual Perception and Action in Sport* (Williams, Davids, & Williams 1999), for example, structured in impressive detail around the contrast between indirect/cognitivist and ecological/dynamical perspectives on perception and action, was barely cited in philosophy. At that stage, little work in the specialist fields of 'philosophy of sport' and 'philosophy of music' made contact with empirical studies or with cognitive theory, focussing instead on ethics, metaphysics, or aesthetics. In turn, discussion of sporting or musical traditions in social science often tended, as Downey (2010) noted, to address ideology and politics to the neglect of embodied expert practice and experience itself.

While applied researchers have contributed to cognitive science and philosophy of mind, relatively few philosophers of mind and cognitive theorists over the last 30 years demonstrated equivalent interest or respect in return. Researchers on skilled action in philosophy and cognitive science alike often advocate more phenomenological and ethnographically informed accounts to further understanding of performance in real world contexts. Yet until recently they rarely acknowledged the extent to which researchers and researcher-practitioners have been doing just that, as we illustrate below. But perhaps we are now entering a more integrative, pluralist phase of expertise research. Alongside attempts to bring cognitive and phenomenological philosophy into contact with sports psychology (Kretchmar 1982; Moe 2005; Aggerholm et al 2011; Ravn & Christensen 2014; Toner, Montero, & Moran 2015; Kimmel & Rogler 2018), a clear sign of change is MIT's grand-scale

*Handbook of Embodied Cognition and Sport Psychology* (Cappuccio 2018), with many chapters co-authored by philosophers and sports scientists, moving multi-disciplinary skill and expertise research along very substantially. We can build on this momentum. Before surveying methods for tapping in to expert practice, we point to two key research targets for the ecological or distributed approach we're developing.

### **Ecologies and cues**

Alongside the embodied experience of expert performers in real domains of practice, we need to study the full, challenging settings in which they attend to particular cues and deploy particular strategies for maintaining or improving performance. Such settings are hard to simulate. Professional athletes regularly navigate factors as various as changing weather conditions, unfamiliar locations or terrain, equipment and new technologies, fatigue, injury, pain, risk, the sounds and expectations of crowds and supporters as well as media, self-imposed or career-threatening pressure, interaction with peers or team-mates under varying constraints, the actions of opponents and other competitors, and strong personal emotions. A number of these factors are in play in our case study from cycling below.

Challenging ecological factors are par for the course, and not outside what we have called 'the conditions of expected skill' for expert performers, to be expected and prepared for even if not encountered frequently from a statistical point of view (Christensen, Sutton, & McIlwain 2016: 52-54; Christensen, Bicknell, McIlwain, & Sutton 2015). Navigating such aspects of the bodily, motivational, collaborative, and environmental settings of performance, while maintaining or intensifying the highest levels of technical competence in skill execution, is utterly unlike reproducing a single isolated component of one's overall skill set in simplified training or laboratory settings, no matter how useful such repeated performance might be for other purposes (Christensen, Sutton, & McIlwain 2015). Professional musicians and dancers face different, but often no less challenging, variations in the settings and contexts of practice and performance. Because experts' work is thus dependent on often unpredictable changes in the distributed ecologies of skilled performance, they deliberately get (as they say) out of their comfort zone, to stay fresh and ready to innovate or improvise. They do not rest easy with repetition of prior actions. To respond to challenge, athletes attune to a range of cues, which help them attend, anticipate, and act appropriately as situations shift.

Sports psychologists have focussed on the advance pickup of perceptual and kinematic cues, which grounds expert advantage in interceptive tasks like hitting a ball (Abernethy, Farrow, & Mann 2018). We'll note below complementary recent work on the role of contextual cues, when experts access and deploy relevant situational knowledge to influence and adjust their well-honed embodied skills in real time. Verbal cues, in the form of self-talk as well as input from team-mates and coaches, often function less as direct instructions than as compressed, context-sensitive nudges to adjust action tendencies (Sutton 2007). Other sets of cues, across skill domains, may be multimodal and overlapping. The roles of multimodal cues in instruction and performance have been studied most thoroughly in other professional fields, including archaeological practice and courtroom debate (Goodwin 1994), agriculture (Grasseni 2004), architecture and design (Rietveld & Brouwers 2017), navigation (Hutchins 2010), and aviation (Hutchins et al 2013). Using microanalytic methods, such research in interaction studies and cognitive ethnography traces the developmental processes of embodied apprenticeship which ground skilled vision, practical know-how, and insiders' context-sensitive banter (Streeck, Goodwin, & LeBaron 2011). With new mobile recording and analysis techniques, such methods will increasingly influence integrative multi-disciplinary research in the arts (Kirsh 2010; Waterhouse, Watts, & Bläsing 2011; Geeves, McIlwain, & Sutton 2014) and sport

(King & De Rond 2011; Collins 2015; Muntanyola-Saura & Sánchez-García 2018), and offer rich pickings for philosophers and cognitive theorists.

### **Methods**

Methods from interaction studies and cognitive ethnography, like those mentioned above, involve probing, listening to, and analysing what experts say about their domain, their activities, and their decisions. They are not vulnerable to the critiques of self-report which have long stopped many philosophers and psychologists from working closely with experts' own accounts of their skilled practice. Poorly controlled collection of verbal report data, it is feared, leaves us with confabulated accounts of cognitive processes, arising from implicit culturally-sanctioned theories, involving causal claims disconnected from the true springs of action. The resulting lack of interest in what experts tell us chimes with longstanding philosophical assumptions that higher levels of skilled performance are intuitive and 'mindless', and therefore cannot be accessed or articulated, assumptions we criticise elsewhere (Sutton et al 2011; Geeves, McIlwain, Sutton, & Christensen 2014; Christensen et al 2016).

Discomfort with self-reports also arises within the relevant sciences. In one trenchant critical review of the use of verbal reports in sport science, Eccles (2012) found that many studies employ overly directive probe questions, tap only general states rather than particular episodes, and involve long delays between action and report. Yet, as Eccles acknowledged, there are methods for tapping experts' embodied experience which do not rely on problematic, theory-infected self-reports. Expert accounts can be treated as further explananda rather than as potential causal explanations. In the interaction research mentioned above, verbal reports are triangulated against arrays of other data on the same events. Most directly, clearer methods for accessing expert reports are available. Participants can be trained to report only on what they have just been thinking, rather than offering interpretations of their cognitive processes. They can be asked to think aloud during performance or, in dynamic sports, to provide immediately retrospective reports on specific episodes.

Protocol analysis of concurrent or retrospective verbalisation is widely used in expertise research (Fox et al 2011; Ericsson 2018). In impressive longitudinal studies of memory and cognition in professional musicians' rehearsals and performances, Roger Chaffin and colleagues record reports by expert pianists, cellists, or singers of their decisions, feelings, and thoughts during practice, sometimes spread over years. They code changes over time and across distinct rehearsal phases in musicians' attention to distinct basic, technical, structural, interpretative, and expressive performance cues. They match these verbal reports against a range of behavioural data, for example identifying the precise points within a score at which musicians stop and start during practice, or quantifying hesitations and the exact tempo profiles of phrases which constitute musical gestures (Chaffin, Imreh, & Crawford 2002; Noice et al 2008; Lisboa et al 2018). First-person perspectives on the stages of practice and the challenges of the musical material are checked against large bodies of longitudinal third-person data, producing powerful multi-level accounts of the roles of different forms of memory in experts' musical practice, and of the nature and role of spontaneity and creativity in highly prepared music performance (Chaffin, Logan, & Begosh 2009).

Likewise, recent research in sport deploys thought sampling and verbal protocol analysis, in iterative, mutually-informing interaction with behavioural methods. McPherson and colleagues find significant differences between the immediately retrospective reports given by experts and novices across sports, in the breadth, depth, and diversity of detailed tactical plans and adjustments in response selection as game situations change (McPherson 2008; Sutton & McIlwain 2015). McRobert's mixed method studies show that experts across a range of sports are thinking more about task-relevant options, and engaging in more prediction and more planning than less skilled performers (McRobert

et al 2011; Ward et al 2013). Experts often effectively integrate broader contextual information – about opponents, past performances, the competitive situation, and the time remaining, for example – with immediate and changing kinematic information, to anticipate and shape appropriate actions. This deployment of contextual information has been confirmed by Runswick and colleagues, who interpret controlled verbal report data gathered immediately after cricket batting tasks in light of independent measures of performance (Runswick et al 2018). Coding the content of these retrospective verbal reports is not the sole source of evidence, but when matched against data on the accuracy of players’ anticipation and action strongly suggests that – in addition to any technical advantage – experts surpass less skilled players cognitively, in their capacity for fast and effective access to and deployment of relevant contextual information.

While there are legitimate concerns about some uses of verbal reports in expertise research, there are also proven, rigorous methods for gathering and analysing them effectively. Yet such controlled procedures do not exhaust appropriate ways of tapping the embodied experience of experts. If our goal is to seek explanatory causal accounts of specific mechanisms underlying skilled performance, we may need that specific kind of verbal report. But because we know so little about the richer cognitive ecologies of performance, the admirably narrow conception of self-report advocated by Eccles and implemented in the research just described will not satisfy all our theoretical needs. Experts’ personal meanings, contexts, individual and shared performance histories, and their long-term experience of embodied action, all which are excluded in the formal protocol analyses described above, might be relevant to other questions. As we have suggested, ‘if certain components of expert knowledge are thus more or less accessible, they are likely also to be shareable with researchers as well as with coaches and peers, provided the researcher establishes a situation of sufficient rapport, asks the right questions, and the practitioner is appropriately motivated and has no reason not to share’ (McIlwain & Sutton 2015: 223).

We advocate a broader range of qualitative, phenomenological, interview-based, and participatory ways of getting nearer to embodied experience. Where possible these can be matched against and meshed with quantitative and nomothetic research, but we should not rush to premature hypotheses and experiments in domains where extraordinary levels of skilled performance may first need to be identified and described in sufficient richness. Phenomenological traditions in philosophy are being creatively adapted in this spirit, for example in Høffding’s development of the phenomenological interview for music and sport (Ravn & Høffding 2017; Høffding 2018). We now discuss more complete immersion in the expert’s world, seeking to access embodied experience in full cognitive ecologies either by ethnographic participation, or by listening closely to an expert’s own account. We look in turn at two ways of approaching skilled action from the inside out.

### **Researcher-practitioners on expert embodied experience**

Experts’ embodied experience unfolds, over time and in the moment, in rich and strange cognitive ecologies. Some researchers are also practitioners, and generate sustained, phenomenologically-informed investigations of skilled action. Researcher-practitioners aim to speak ‘with and for us’ in tapping and articulating embodied processes. We are not thinking here of academics discussing their casual explorations of skilled action, because novice or recreational performers cannot always access the embodied experiences of experts, and thus cannot go beyond anecdote to offer rich detail in reports. Apprenticeship-based study requires persistence, whether through immersive fieldwork to ‘dive into the stream of action’ and report back (Wacquant 2015), or to draw on embodied practical knowledge in interpreting others’ accounts.

Through long-term immersion in the rich ecologies of expert activity, researcher-practitioners can feel and evoke the distributed but integrated webs of bodily, cognitive, affective, technological, and cultural resources and strategies which characterise their domains. Doris McIlwain draws on years of

experience in two yoga traditions to analyse their very distinctive norms for sculpting embodied habits, involving different kinds of cue and instruction, and different ways of dealing with emotion, bodily tension, or 'silent zones', as different metaphorical and metaphysical systems pervade bodily practice over time (McIlwain & Sutton 2014). In exploring the way men experience, or do, masculinity in surfing, Clifton Evers (2009) shows how multiple interacting forces— sand, wind, water, affect, behavioural codes, skill, perception, equipment, cultural histories, shared embodied practice—together shape social experiences, identity and bodily movement. Ian Maxwell's (2016) thick descriptions of the embodied experience of being at sea likewise reveal the dynamic, co-constitutive ecology of bodies, environment, and equipment in sailing: no element of the experience can be adequately described in isolation from its relationship to the others. Kath Bicknell draws on her embodied experiences in mountain biking over two decades to unpack performance processes and strategies in herself and others. Addressing distinctive aspects of embodied expertise, she describes mutually beneficial audience-spectator relationships in racing contexts (Bicknell 2010, 2011), the behavioural and social implications of technological trends for women's experiences in mountain biking (2015), and how increases in skill retune experts' sense of agency and perception of affordances (Christensen et al 2015; Christensen & Bicknell 2018). We add pointers to practitioner-based studies of sport and movement expertise through autoethnography (Allen-Collinson 2009), apprenticeship and neuroanthropology (Downey 2005, 2010; Downey, Dalidowicz, & Mason 2015), and carnal or enactive sociology (Wacquant 2014, 2015). These approaches, making contact variously with 4E cognitive theory, seek experientially-grounded paths to richer understandings of skill. By inhabiting a world and at least partially setting aside the spectatorial posture of the researcher, these phenomenological and ethnographic projects approach expert action in the making.

### **Case study: Chloe Hosking's winning sprint**

Another way to prioritise insider perspectives is through data produced by and for people within the expert subculture, such as interviews, social media, video footage, or post-event blogs. Unprompted athlete reports can counteract the pervasive assumption that experts cannot articulate or explain what they did in performance, or how they did it. Our final case study, built around Chloe Hosking's blog on her winning ride in the 2016 La Course by Le Tour de France (Hosking 2016), shows the range of embodied experiences some athletes can articulate. It goes some way towards elucidating the calculations and fine-grained tactics in road cycling which intrigue and mystify fans and commentators, who can only wonder why 'some riders are better at these computations than others' (Papineau 2017: 128-9). Bicknell's expertise as cyclist, researcher, and cycling journalist helps us interpret Hosking's report. It was published four days after Hosking won La Course, at the time the highest profile event, globally, in women's road cycling.

The delayed and self-reported nature of a blog post raises questions about the reliability and validity of Hosking's recall. But examined with a critical eye, such sources provide insight into expert embodied experience which may be unavailable by other means. Hosking's blog relays her *experience* of the race, from inside the peloton, where video cameras were absent, thought-sampling methods impractical, and the actions of over a hundred other athletes too variable to simulate with intensity in a lab. We can supplement and triangulate her blog post against independent sources, including video footage of the race and Hosking's own initial reactions after winning (Voxwomen 2016). The blog elaborates or unpacks Hosking's decision-making processes during the event. Athletes frequently recall in considerable detail significant moments and decision-making processes as critical moments unfold. We suggest not that Hosking's report is unflinchingly accurate, but that it does reflect factors that inform decision-making during performance.

La Course by Le Tour de France was a 13-lap race on the Champs-Élysées. Each lap was just under seven kilometers, and each took the leading riders between nine and ten minutes. In Hosking's team, Wiggle High5, she was the protected rider if the finish became a bunch sprint. This was one of the team's several strategies for the race depending on how it unfolded (Wiggle High5 2016).

As you read Hosking's description of the race's closing phases, note how she quickly accounted for the tactical decisions and anticipated movements of her competitors in relation to her own abilities as she decided who to follow and when.

... all of a sudden Ellen van Dijk shot out of the peloton and down the ramp into the tunnel faster than you backtrack when you say you'll come to something with your family and then find out you have to pay. She obviously hadn't read the script, this was meant to be a bunch sprint.

I literally thought, 'oh shit'. I had no one left, they had done their jobs already, and I learnt after the race, had all been caught in crashes. I couldn't chase Ellen myself. I had to wait.

The Canyon-SRAM team obviously felt the same sense of urgency as I did and flicked out of the compact group in pursuit of Ellen who had already established a solid gap with about 1.5kms to go.

The issue was there was only two left in the Canyon train — Alena Amialiusik and Tiffany Cromwell — and one of them had to sprint leaving only one to chase Ellen, a former world time trial champion. Positioned third and glued to Tiffany's wheel as we powered towards the final kilometer I was willing Alena to keep going but I could see her starting to rock on her bike. We weren't going to catch Ellen.

While this move may not have been in Hosking's script, van Dijk revealed in a post-race interview that it was her plan to attack at this point in the race all along (UCI Women's World Tour 2016). Hosking's report does not describe one single decisive moment that won the race, but reflects a series of decisions and moments which added up to her navigating the final moments of the race most successfully. She had to flexibly adapt her strategy for sprinting to the line without her team for support. She chose not to chase van Dijk solo as it would have used up too much energy. The blog reveals clear appreciation of what she *can* do (draft on the wheels of other riders), *cannot* do (chase van Dijk solo and hold off the chasing peloton for over a kilometer) and *might* be able to do (adapt again if circumstances change). Her rapid assessment of the unfolding situation drew not only on years of experience as a professional cyclist, but on strong contextual knowledge of the capabilities of her rivals. Hosking was aware van Dijk had the capacity to pedal away given her time trial credentials. Hosking was also observing her rivals for cues and clues about their form in the moment: Amialiusik's rocking body revealed she was struggling and would be unlikely to sustain her power output.

Then as we rode under the 1km to go banner I could feel riders coming up on the right hand side. I started to move out and somehow found myself on Pauline Ferrand-Prevot's wheel. She was flying. She took it through the two last corners but Ellen still had twenty meters on the peloton with 350 metres to go.

And then Pauline swung to the right. She was done. I was on the front. This is way too early.

According to the website Strava, where some athletes make their GPS data public, the final 400m of La Course took 2014 winner Marianne Vos approximately 28 seconds (Strava 2016). While Hosking

didn't share her own data from the 2016 race, 15th place finisher Sarah Roy, who rode across the line with the bunch just behind Hosking, took 30 seconds. A lot can happen in those final critical seconds. With Prevot gone, van Dijk in front, and a motivated peloton behind her, Hosking was on her own.

It is amazing how much actually goes through your head in a sprint, it seems like you have minutes to make decisions but really it's milliseconds. I decided to go. I figured I could jump and maybe hang on for a podium or get swamped and come away with nothing.

Hosking obviously wanted to win, but made the decision which gave her the best chance of a podium position, rather than focusing exclusively on the win. She didn't take the shortest route to the line. She rode tactically given the wind and the brief respite she might get before kicking again. She continued to monitor the situation, and other riders, all the way to the line. She also monitored parallel experiences of time: the gap to van Dijk, her sense of pace and of how long she could hold it given the two hours racing already, and the anticipated time to the finish line.

With Pauline in the middle of the road and Ellen glued to the barriers on the left hand side of the road I put the power to the pedals and steered my bike for Ellen's back wheel. I figured I could run at her wheel and maybe use her as a wind break to close the last few meters. I must have passed her with 200 metres or so to race. Then I just had to keep going.

With my elbows out and head down I just tried to put everything through the pedals. I was looking under my arms to see if any wheels were creeping up behind me but nothing came. The finish line kept getting closer and no one was coming around me, 'this can't be real'.

Then I won La Course by Le Tour de France.

### **Learning from the cognitive ecologies of experts**

To win a sprint in a bike race requires considerable strength to ride harder and faster than the competition, especially when they are the best in the world. Hosking's report shows that it also involves finely tuned cognitive capacities to mediate between distinct aspects of embodied expertise in the race's crucial final minutes. She drew on a range of anticipatory cues to time the release of energy, to monitor the wind, ground surface, other riders, and her internal state. Then she narrowed down alternate courses of action as the race became (predictably) unpredictable. We see evidence of previous experiences at different timescales informing the decisions she made in high-pressure moments. Hosking's focus was so heavily on how to *tactically* navigate the final two laps of the race that she barely even mentioned controlling her bike on the uneven cobbled surface of the Champs-Élysées, save for putting power through the pedals and steering it toward van Dijk.

Reports like Hosking's are not unusual in cycling. Alongside other sources, athlete-generated accounts help researchers explore and tap into the mechanisms informing embodied expertise. Hosking's description helps us appreciate that it's not simply that some riders are better at computing real-time decisions on when to go hard and when to wait. She lets us in on her ongoing assessment of this situation and these specific competitors (their histories, strengths, and current form), in this specific place (slightly uphill, cobbled road, into a headwind). When the way the race unfolded meant Hosking had no teammates to lead her out for the sprint as planned, she solved problems on the fly under pressure, making quick choices based on the best chance of finishing well.

In this engaging case study, individual history and embodied experience matter, as the basis of adaptability in the moment. Here we prioritise expert insight into the settings where the relevant

skillsets are regularly deployed. As researchers interpreting Hosking's words, we co-construct an account, letting the athlete speak for herself from her integrated world of practice. This serves our multi-disciplinary agenda, as the expert's perspective guides us in exploring the idiosyncratic, context-specific ways that the features of the cognitive ecology of performance operate together. Being open to athletes' communications from within their sporting worlds, to audiences familiar with the subtleties of performance in these contexts, is one effective way among others of understanding the embodied experience of expert performers in real domains of practice, as they deploy richly embedded strategies in full and challenging ecological settings, where multiple stimuli, plans, tasks, and pressures compete for attention. We can learn much about skill and expertise if we work with real experts in the environments to which their expertise is so intelligently attuned.

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