*** Penultimate Draft: Published in P. Henne & S. Murray (eds.), *Experimental Advances in Philosophy of Action* (pp. 33-50). New York, NY: Bloomsbury Publishing, 2023. Please cite published version only.**

Skilled Action and Metacognitive Control

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1. Introduction

A skilled agent exercises a high degree of control in some action domain as the result of extensive practice. A theory of skilled action aims to specify the precise nature of such control. This is the topic of this chapter.

I start by tracing the early stages of skilled action theory, which focused primarily on the nature of the practical knowledge that skilled agents possess, to more recent stages, which look to cognitive science for insights about the control processes underlying skill. I then distinguish between two competing views in the current literature: 'automatism', which takes skilled action control to be driven by "mindless" automatic motor control processes with little to no intervention from cognitive control, and 'cognitivism', which views thought and cognitive control as being at the heart of skilled action. I motivate cognitivist views and outline some advantages they have over their automatist counterparts. I then highlight an unsatisfied desideratum of such views: a general account of *how* exactly the cognitive control processes to which they appeal, e.g., situational awareness, focus, and attention, interact and coordinate with automatic control processes. I propose that in order to answer this question, one must appeal to a certain type of *meta*-control, over *both* automatic and cognitive control processes, that skilled agents possess in the form of metacognition. In the last two sections, I explain the importance of metacognition for skilled action control and how it may account for aspects of the subjective experiences that are characteristic of skill.

2. From Epistemology to Cognitive Science

Contemporary theorizing about skilled action began by looking at the phenomenon from a predominantly epistemological lens. Through this lens, skilled performers are agents *par excellence* in virtue of the practical knowledge, or know how, that they possess with respect to some type of activity. A theory of know how can thereby do double-duty as a theory of skill: once we understand what it is to possess and exercise practical knowledge, we understand what sets apart expert performers from mere novices. But how should we understand the nature of know how?

So-called intellectualists argue that practical knowledge is just a type of theoretical knowledge ('knowledge-that') and should be understood in terms of an agent's standing in a certain relation to a proposition or set of propositions concerning how to perform some action type. An early opponent of this view was Gilbert Ryle (1949/2009). He argued against what he called the 'intellectualist legend', according to which what it is for an agent to know how to Φ is for them to consider the appropriate proposition or rule prior to applying it to their present action, i.e., for the agent to exercise suitable theoretical knowledge about the activity of Φ-ing.

According to Ryle, such a view fails for a variety of reasons. First, knowledge how does not seem to be *sufficient* for knowledge that. After all, one might know how to perform some action skillfully without being able to verbally express or articulate the knowledge they possess in propositional form. Second, knowledge how does not seem to be *necessary* for knowledge that. One might know a set of propositions corresponding to the skill of cycling, for example, yet not know how to ride a bicycle. Finally, it would seem that knowledge how must *precede* knowledge that, since applying a rule correctly is itself something one must first know how to do. But if this know how itself requires the appropriate application of a rule, then we are off on an infinite regress.

Ryle's anti-intellectualist arguments remained largely unscathed until the publication of a landmark paper by Stanley and Williamson (2001), which not only criticizes Ryle's main arguments against intellectualism but also mounts a positive case in its favour. Their case relies on observations about the syntax and semantics of ascriptions of knowledge-wh states (e.g., ascriptions of knowledge where, knowledge when, knowledge why) of which knowledge how is a type. In short, they argue that all knowledge-wh ascriptions are ascriptions of knowledge that and this is suggests that knowledge how is a species of knowledge that. On Stanley and Williamson's view, knowing how to F is equivalent to knowing in what way to F, and this is a form of propositional knowledge, i.e., knowing of some way w of F-ing, *that* w is a way to F, under a practical mode of presentation (the nature of which remains to be elucidated, see Pavese 2015).

One of the main lines of criticism against Stanley and Williamson's position is that the methodology it pursues in order to establish that knowledge how is a species of knowledge that is problematic. Thus, Noë (2005) advances skepticism regarding the relevance of technical linguistic analysis to the debate on the grounds that what is at issue is not how *attributions* of knowledge how and knowledge that work, but the very nature of knowledge how and knowledge that. Similarly, Devitt (2011) argues that Stanley and Williamson's methodology of constructing a theory of knowledge how on the basis of a linguistic theory of ascriptions without looking at the science of knowledge how is deeply misguided. Likewise, in a recent paper Levy (2017) urges that whether knowledge how can be reduced to propositional knowledge is partly an empirical issue, arguing ultimately that the relevant science indicates that knowledge how has a non-propositional component.

Theorizing about skilled action control, including in later work by Stanley (Stanley and Krakauer 2013; Stanley 2011), has since taken what might be called a *cognitive scientific turn*, with insights garnered from work in cognitive neuroscience, cognitive psychology, computer science, and cognitive ethology (see Schwartz & Drayson 2019 for discussion of this shift in methodology). Some of this work still focuses on the relationship between theoretical and practical knowledge. Thus, Devitt argues that the folk's theoretical and practical knowledge should be viewed as equivalent to the psychologists' declarative and procedural knowledge and that the empirical evidence that the two dissociate strongly suggests that they are distinct. And both Devitt and Noë argue in favour of anti-intellectualism on the grounds that cognitive science has by and large characterized practical knowledge in non-representational terms (i.e., as involving embodied capacities), while Roth and Cummins (2011) argue that even where cognitive scientists treat practical knowledge as involving representations, they are not considered to be propositional in format.

The cognitive scientific turn has expanded the scope of theorizing about skill in a way that has taken it beyond concerns about the relationship between practical and theoretical knowledge and the nature of each. The emphasis, instead, has come to be on the nature of the *control* that underlies skilled action. In general, we may say that what it is for an agent to possess control is to possess the capacity to bring about mental or physical activity in accordance with their goals. When it comes to skilled action control, the question concerns the extent to which such control is subserved by psychological processes associated with higher-level cognition and propositional representations vs.

those psychological processes that proceed automatically, and are associated with the motor system and non-propositional representations. In light of this broader focus, characterizing the debate as being one between intellectualists vs. anti-intellectualists seems no longer apt, since all parties agree (see, e.g., Stanley & Krakauer 2013; Pavese 2019) that skilled action control is not exhausted by propositional knowledge. Rather, the debate is now better construed as holding between what we might call *automatism*—the view that skilled action control, under optimal circumstances, is largely driven by automatic motor processes—and *cognitivism*—the view that skilled action control, under optimal circumstances, essentially involves significant contributions from cognitive control.

The two competing views may be characterized more precisely as follows:

Automatism: Under optimal circumstances (i.e., not novel or otherwise unpredictable), skilled action is primarily driven by automatic motor control processes that are characterized by a lack of (i) conscious reflection about what the agent is doing, (ii) explicit intention guiding one's behaviour each step of the way, (iii) monitoring and attention directed towards what the agent is doing, or (iv) deliberation or reasoning about what the agent is doing.

Cognitivism: Under optimal circumstances (i.e., not novel or otherwise unpredictable), skilled action control is primarily driven by cognitive control processes that are characterized by the presence of (i) conscious reflection on what the agent is doing, (ii) sustained focus on the agent's intention, (iii) monitoring and attention directed towards what the agent is doing, or (iv) deliberation and reasoning about what the agent is doing.

In the next section, I look more closely at the debate between these two views, and motivate a form of cognitivism.

3. Automatism vs. Cognitivism About Skill

According to automatism about skill, skill acquisition is characterized by an increase in automaticity and reduced involvement of cognitive control at advanced levels (Anderson 1982; Fitts & Posner 1967; Dreyfus & Dreyfus 1986). On such a view, novices start out learning a skill by following step-by-step rules or procedures and explicitly thinking about what they are doing. But once they have advanced to higher levels of skill by automatizing the motor routines involved in various tasks through extensive practice, there is no longer any need for them to direct cognitive control—in the form of conscious attention and monitoring—towards their performance. These and other forms of cognitive control (e.g., focus, reflection) might be required in novel or unpredictable circumstances, such as when an experienced driver is trying to navigate an unfamiliar route during poor road conditions, but under normal or typical circumstances, skilled performance unfolds without them.

A standard argument in favour of automatism appeals to a phenomenon known as "the yips". Expert performers who suffer from the yips repeatedly perform below their own baseline level in high-pressure situations, despite the absence of any physical injury. Importantly, the yips typically interfere with heavily automatized, routine behaviours that experts can normally perform without any difficulty, such as throwing the ball to a teammate in baseball.

According to one prominent theory, known as "explicit monitoring theory", in cases of the yips, performances are not hurt because one is anxious or worried about them, but rather because of the self-directed attention that results (Beilock 2010, p. 193). What is thought to happen is that the agent's anxiety, triggered by the high-stakes scenario within which they find themselves, causes them to turn their attention inward, thus self-consciously monitoring motor routines that would normally

proceed automatically. According to the theory, it is this monitoring of and attention towards their own activity that interferes with their ability to perform (Baumeister 1984; Masters 1992; Wulf and Prinz 2001; Beilock and Carr 2001; Beilock et al. 2007; Ford et al. 2005).

Support for explicit monitoring theory comes from a range of empirical studies that use what is known as the "varied focus" paradigm (e.g., Beilock & DeCaro 2007; Ford et al. 2005; Gray 2004). Here participants are divided into two groups: the highly skilled group and the novice group. Both groups are asked to perform the same task (e.g., dribbling a soccer ball) under three conditions: (i) normal, i.e., perform the main task on its own ("single-task/control condition"), (ii) while directing attention to some aspect of their performance (e.g., what side of their foot last touched the ball when an auditory tone occurred) ("skill-related supplemental task condition"), and (iii) while engaging in an extraneous task (e.g., counting backwards by twos) ("skill-unrelated supplemental task condition"). Participants in the highly skilled group perform significantly worse (vs. the normal/control condition) in the skill-related supplemental task condition, but only negligibly worse in the skill-unrelated supplemental task condition. Novices show the reverse pattern, performing significantly worse in the skill-unrelated supplemental task condition (vs. the control condition) and marginally better in the skill-related supplemental task condition (vs. the control condition)

One explanation for why highly skilled participants perform only negligibly worse in the skill-unrelated supplemental task condition accords with automatism. In light of their ability to perform the primary task automatically, highly skilled participants have conscious monitoring and attentional resources to spare. These can be used for the skill-unrelated supplemental task, but they should not be directed towards movements that have already been automatized and typically proceed in the absence of monitoring and attention. By contrast, novices do not have extra cognitive resources left for supplemental tasks—they must direct attention to their bodily movements to ensure they are proceeding smoothly. According to some, these "findings clearly show that if experienced individuals direct their attention to the details of skill execution, the result is almost certainly a decrement in performance" (Wulf 2007, p. 23).

From these empirical considerations, proponents of automatism argue that a central prediction of the view, i.e., that conscious attention and monitoring is disruptive to expert performance, is borne out, thus lending it significant support.

But in recent years, several theorists have pushed back on this line of reasoning. In particular, some have argued that we can allow that conscious monitoring and attention to implementation of automatized motor routines is detrimental to performance, while maintaining that (other varieties) of cognitive control are essential to skill even under normal or optimal conditions. For instance Papineau (2015) argues that focus on one's present goal and "keeping one's mind right" are crucial for successful skilled performance, while agreeing that attending to the details of one's motor routines—what he calls the components of basic actions—will result in disaster. Similarly, Bermúdez (2017) argues that certain forms of reflection are essential to skill, since such states are required for appropriately structuring one's attention to relevant aspects of the situation of action, while allowing that the yips are caused by attending to the detailed components of our actions. And Christensen et al. (2016) emphasize the importance of "situational awareness", which involves the moment-by-moment perception of task-relevant features in the environment in a way that enables the agent to anticipate what will happen next, thus adequately preparing them to respond.

The recent interest in the various roles that cognitive control plays in skill, which are not restricted to conscious monitoring and attention of one's bodily movements, has resulted in theorists seeking to develop cognitivist accounts of skilled action control that reserve substantive roles in skilled performance for *both* cognitive control processes and automatic forms of control, even under optimal conditions (Christensen et al. 2016; Fridland 2014, 2017; Levy 2017; Montero 2016; Papineau 2013, 2015; Shepherd 2019; Toner & Moran 2020; Bicknell 2021). The central

commitment of such views is that automatization "frees up" cognitive resources that are then reinvested such that they continue to contribute to performance even at advanced levels of skill. Further, such views take on a more nuanced understanding of automatic motor control processes according to which they are not merely brute, rigid, reflex-like responses, but flexible and intelligent in their own ways (see, esp., Fridland 2014, 2017). Importantly, cognitivist accounts treat both cognitive and automatic control processes as richly integrated, coordinating to help the skilled agent smoothly satisfy their goals. As such, these views are required to articulate how it is that cognitive and automatic control processes interact.

Cognitivist views of skill have much going for them. For one, they are well-motivated by considerations pertaining to the variability of circumstances under which skilled agents perform. When selecting what action to perform in a given context, skilled agents must be finely attuned to a wide range of situational features. For instance, in tennis, the choice of the type of shot and how to make it will depend on factors such as wind conditions, court surface, the opponent one is playing, their positioning, and so on (Nadal & Carlin 2011, p. 6). A second motivating consideration, emphasized by Christensen et al. (2016), is that a *familiar* task is not necessarily an *easy* one. This means that even if an expert has performed a certain type of action countless times, some actions may be so difficult and challenging that they can never be fully automatized.

In attempts to flesh out versions of cognitivism, theorists argue for the role of different aspects of cognitive control in skill that go beyond explicit monitoring and thought (Montero 2015, 2016) such as top-down, selective attention (Bermúdez 2017), focus and concentration (Papineau 2015), situational awareness (Christensen et al. 2016) and strategic control (Fridland 2014).

This is all well and good. Certainly an overly narrow emphasis on explicit monitoring is problematic if one wants to give a comprehensive account of the range of cognitive control processes underlying skilled action. But while we can (and should) grant that cognitive control that goes beyond explicit monitoring of bodily movements is crucial to skill, one might nonetheless allow, as many cognitivist theorists do, that in many scenarios and skill domains, explicit monitoring and attention to the implementational details of one's action is detrimental. If this is right, as I think it is, then we are left with an important question that requires an answer: how does a skilled agent ensure that the implementational details of their performance unfold smoothly if not via explicit monitoring and attention? Furthermore, how is it that the agent can flexibly *integrate* cognitive and automatic control processes, knowing when and how much of each is needed at any given moment?

It seems to me that in order to answer these questions, we must appeal to an overarching type of meta-control process that is directed towards *both* cognitive and automatic control and helps to integrate them. I submit that skilled agents differ from novices due significantly to their enhanced metacognitive capacities. Metacognition may play a number of roles in skilled performance, but here I will emphasize its role in regulating automatic motor control processes, as well as its role in guiding the interplay between cognitive and automatic control processes. Thus, metacognition may be seen as a form of meta-control that no skilled performance goes without. I will also argue that an appeal to metacognition can help us better understand aspects of the distinctive phenomenology of skill. Before turning to these issues, I next offer a brief account of metacognition.

4. What is Metacognition?

4.1 Metacognition as Metacontrol, Not Metarepresentation

Metacognition is often characterized as a capacity for self-knowledge that is acquired when the mind turns in on itself. Thus, Flavell (1976) writes, "[m]etacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them" (p. 232).

Some who subscribe to this general view supplement it with the further claim that this capacity for self-knowledge relies on the same mechanisms that enable us to acquire knowledge of *other* minds, i.e., our so-called "mindreading capacities" or "theory of mind" (Premack & Woodruff 1978). On this picture, our third-person theory of mind capacities are *meta*representational: when I attribute a belief that it is raining to John, I do so by way of metarepresenting him as being in a mental state with that representational content. Metacognition, understood in this way, is simply one's theory of mind applied to oneself, and is thus seen as a form of first-person metarepresentation (Carruthers 2009, p. 121).

While popular, this way of thinking about metacognition falls short in that it fails to emphasize that a main function of metacognition is the *control* of one's cognition and behaviour, not *merely* acquisition of self-knowledge. This is why, for example, the bare act of introspecting on one's thoughts in the stream of consciousness without any subsequent use of the knowledge gained for the purposes of control, is not properly construed as an instance of metacognition. In addition to the mere monitoring of some cognitive process or a feature thereof, there is an evaluative component regarding the success of that process, and this feeds into a control component that is sensitive to this evaluation in deciding what to do

As a paradigmatic case of metacognition understood as such, consider that which results in judgements of learning. These are characterized as judgements that occur during or after the acquisition of some target information (e.g., word pairs) and pertain to the likelihood of success in the future retrieval of the target information. Here, the monitoring aspect of metacognition is directed towards the acquisition process itself, the evaluative aspect is directed towards its success relative to future retrieval, and the control aspect is directed towards actions being taken as a result of the outputs of monitoring and evaluation, e.g., allocating a longer amount of study time or terminating study (see Nelson & Narens 1990). Given this central control function of metacognition, the definition that I favour is as follows:

Metacognition: The capacity to monitor and evaluate one's own psychological processes for the purposes of control.

And since the psychological processes that metacognition targets are themselves control processes, i.e., directed towards some goal, at its core, metacognition is a form of meta-control.

4.2 Metacognition as directed towards control processes, not representations

A second feature of metacognition to emphasize is that it makes use of metacognitive representations, which are representations of a feature or set of features of a psychological process (Shea et al. 2014, p.187). Note, crucially, that I do not say that metacognitive representations are representations of features of r*epresentations*, but representations of features of *processes*. This stipulation is a departure from the characterization of metacognition as metarepresentational. On my view, this characterization is inaccurate, as metacognitive representations are not, strictly speaking, about features of first-order representations, but rather features of first-order psychological processes that tend to yield representations as outputs.

Why insist on this understanding? First, if we look to paradigm cases of metacognition in the psychological literature, including judgements of learning that were just discussed, it is pretty clear that it is *primarily* directed at the likelihood that a given psychological process has resulted or will result in an accurate or successful outcome rather than the outcome itself. For instance, metacognitive judgements of learning reflect one's confidence that one has accurately understood some target material (Nelson and Narens 1990). Likewise, feeling of knowing judgements in

metamemory tasks reflect one's confidence that one will be able to successfully recall some currently nonrecallable item in the future, e.g., on a retention test (ibid). And metacognitive confidence judgements in perceptual decision tasks reflect one's confidence that one has accurately detected some target stimulus or discriminated one of its features (Fleming & Daw 2017). In none of these paradigm cases of metacognition does the metacognitive representation refer to the representation that is the output of a psychological process – it refers to features of the process itself.

Looking to paradigm cases of metacognition also indicates that metacognitive representations do not *themselves* result in the *attribution or awareness* of a psychological state that is the output of a psychological process. The best illustration of this comes from feeling of knowing judgements. Such judgements do not make one aware of the psychological state that will or will not be the future output of the retrieval process – one does not yet have access to this state. They pertain to the retrieval process itself.

To be clear: I am not claiming that metacognition cannot be directed towards a process that outputs a representation of which one comes to be aware. This often happens. For instance, in a perceptual decision task, one is typically aware of the perceptual state that gives rise to the decision. Nonetheless, metacognition (in the form of confidence judgements) is here primarily directed towards the reliability of the perceptual process that gives rise to the conscious perceptual state, and not the perceptual state itself.

4.3 Two Levels of Metacognition

Many theorists have found it fruitful to think of metacognition as operating at two different levels, each involving a different structure, functional role, and type of representations (e.g., Koriat 2000; Arango-Muñez 2011; Proust 2013). I will adopt the same framework here. On such a model, two types of metacognitive capacity are differentiated.

At what I will call "low-level" metacognition, the metacognitive representations deployed in the monitoring and evaluation of first-order psychological processes are non-conceptual "feelings", i.e., states with qualitative character for which there is something to be like when they are conscious. Metacognitive feelings do not require the possession or deployment of concepts corresponding to the psychological processes that they are about in order to be tokened. They belong to the same family as other representations that have non-conceptual qualitative character such as emotions, pains, and visual sensations. These metacognitive feelings, when tokened, constitute a metacognitive evaluation that is primarily sensitive to the *fluency* of the psychological processes towards which they are directed. Fluency can be understood as a function of the ease with which some psychological process is carried out. What this amounts to depends on the type of psychological process in question. In the case of perception, it is taken to mean a lower signal-to-noise ratio (Whittlesea and Williams 2001). In the case of memory or learning, it is often taken to correspond to self-paced processing time (Undorf & Erdfelder 2015). Since these feelings reliably carry information about the success of psychological processes, they can be used by the subject to directly guide subsequent decisions and behaviour, and in the absence of explicit thought or reflection.

A main motivation for positing this basic, lower-level form of metacognition is a body of empirical work that suggests that non-human animals (e.g., rhesus macaques) possess metacognitive capacities, as measured by their performance on metacognitive tasks, but fail false belief tasks[1]. For

[1] Whether it is ultimately correct to claim that non-human primates are incapable of passing false belief tasks is a matter of debate, which for present purposes I must bracket. But see, e.g., Lewis & Krupenye 2021 for an overview.

instance, when both bottlenose dolphins and rhesus macaques are offered the opportunity to 'opt out' from perceptual decision or memory retrieval tasks, they show a similar pattern of responses to human subjects presented with the same tasks (Hampton 2001; Smith 2009). If this is correct, then it suggests that the metacognitive representations they employ for the purposes of those tasks are not conceptually encoded, but rather non-conceptual, qualitative states.

A second type of metacognition, which I will call "high-level" metacognition, operates by way of verbally expressible, conceptual representations with propositional format and is thought to be unavailable to creatures that do not possess the relevant concepts. This is the type of metacognition that is often assimilated to self-knowledge, as it was discussed above, though we will not lose sight of the control function it is meant to serve. The metacognitive representations it uses deploy concepts that correspond to the psychological processes towards which they are directed, such as remembering, perceiving, and learning. It is standard to view higher-level metacognition as requiring mind-reading capacities or theory of mind for extracting the standards of evaluation of a given psychological process (Arango-Muñez 2011; Carruthers 2009). The evaluation such states express tracks their success or accuracy by way of sensitivity to various cues, external and internal, including metacognitive feelings themselves.

There is dispute about how exactly these two posited systems interact. But all agree that, at the very least, the outputs of low-level metacognition are available to be used as inputs by the higher-level. For instance, a feeling of perceptual fluency is available as input to the higher-level metacognition that gives rise to a perceptual decision. And a feeling of knowing is available as input to high-level metacognition that gives rise to feeling of knowing judgements. This is not to say that the outputs of low-level metacognition must be used as input by the higher-level. Indeed, an agent can override their influence in cases where metacognitive feelings may be leading them astray. The point is that they are available to be used as cues by high-level metacognition.

With this conceptual framework in place, I go on in the next section to explain how it is that metacognition is crucial to the meta-control that skilled agents exhibit.

5. Metacognition and Skill

In this section, I will argue that metacognition is crucial to the control that skilled experts deploy in that it makes available a form of action monitoring and evaluation for the implementation of intentions that does not disrupt performance and allows them to balance the interplay between cognitive and automatic control.

First, a brief word about control. Any system capable of adaptively controlling its behaviour must be capable of setting a goal or an aim, predicting the effects of the action that is selected as a means towards satisfying that goal, and comparing the actual effects with those predicted, making adjustments as necessary. The motor system is no different.

Second, a concern to address: Some would balk at the suggestion that metacognition can be directed towards agency *tout court*, insisting that it is specific to mental or cognitive forms of agency. For instance, Proust (2010) argues that bodily actions are constitutively governed by an instrumental norm, such that what it is to act with one's body is to aim to change the world in a certain way and to pursue the means sufficient for bringing about changes in accordance with that aim. Metacognitive processes directed towards bodily action would thus have the function of evaluating the success of an action by comparing its sensory outcomes with the guiding intention. But in addition to any instrumental norms, according to Proust, mental actions involve "epistemic requirements". And it is sensitivity to different epistemic requirements associated with different mental action types (e.g., correctness, exhaustiveness, relevance, informativeness) that metacognition is specialized for, not simply the success of an action relative to one's aim or intention.

Proust's characterization of bodily agency and the instrumental norm it is governed by is likely true of many everyday action types that simply aim towards satisfying some intention. But what we are interested in here is skilled action, i.e., action *par excellence*, and not just basic everyday activity. And in this context, it is clear that a broader set of norms applies in that an agent need not merely satisfy a certain goal or intention, but do so *well*, and this requires adhering to standards such as efficiency, smoothness, accuracy, and so on. It is here that metacognition can (and I think does) play a role that is analogous to that which it plays in mental agency in that it can monitor and evaluate various context-sensitive cues, both internal to external to action control mechanisms, that carry information about the extent to which those norms are met and inform control processes directed toward ensuring that they are. This form of metacognition pertains to performance as a whole, and not just the extent to which individual goals are satisfied.

In fact, the very limited discussion of metacognition in the skill literature lends support to this picture. In a series of qualitative studies examining expert/novice differences in the use of metacognitive processes in endurance runners, Brick et al. (2015a) interviewed ten-elite level endurance runners. They then analyzed their interview data with an eye to determining the extent to which they used metacognitive processes in order to regulate their online performance. One form of metacognition that elite runners reported using was monitoring during running, which included the monitoring of internal sensory events, e.g., bodily sensations of muscular fatigue, breathing, overall feelings of effort or difficulty, and exertional pain. They reported using these cues to inform their choices of further strategies to deploy for enhancing their overall performance, e.g., the use of an active self-regulatory strategy vs. the use of a distraction strategy. In a follow-up study focused on recreational instead of elite runners, Brick et al. found that participants used significantly fewer metacognitive strategies than experts and deployed them less effectively and flexibly.

The type of metacognition just described corresponds to what we earlier characterized as higher-level metacognition and is of a variety that the agent explicitly intends to engage in. Here the outputs of metacognition are judgements pertaining to aspects of the skilled performance and are based on a conceptual understanding of the type of action in question and on factors that contribute to its going well. We can call the judgements in question judgements of performance. Importantly, the monitored cues (e.g., exertional pain) that such judgements are based on can include elements external to the motor control processes responsible for bringing about the relevant action outcomes. What is important is that these cues carry information about the extent to which the performance is going well, which includes information about how much effort is being exerted and the extent to which overall task demands are being met. The judgements of performance that the agent forms on their basis can then help dictate what aspects of the performance might need to be adjusted or regulated as well as how—in particular, which aspects of the performance might benefit from additional forms of cognitive control.

But not all forms of action-related metacognition are carried out in this explicit manner. I propose that it is implicit, low-level metacognition in the form of feelings of dis/fluency that regulate the motor control processes that implement an agent's goals, analogously to how they regulate mental processes such as remembering, learning, or perceiving.

A range of studies provides evidence that one of the main cues to which metacognitive feelings of fluency are sensitive in the context of motor control is the *ease or smoothness* of action selection, i.e., the degree of response conflict or competition that is present on a given task. In general, these studies use subliminal priming of actions to manipulate the ease of action selection in simple response-selection tasks (Chambon and Haggard 2012; Chambon et al. 2014; Sidarus et al. 2013, 2017; Voss et al. 2017; Wenke et al. 2010). In one such study, participants were asked to press left or right keys corresponding to left or right pointing target arrows, i.e., to perform a left-key press in response to a left-pointing arrow and a right-key press in response to a right-pointing arrow. Prior to

the appearance of the target arrows, they were presented with *subliminal* arrow primes that were either compatible or incompatible with the target arrow. After they gave their response, and with variable delays, they were presented with disks, the colour of which depended on whether the primes were compatible or incompatible with the correct response. At the end of each block, participants were then asked to rank-order how much control they experienced for each colour that appeared, i.e., to make judgements of control.

Unsurprisingly, participants' reaction times were faster for compatible primes vs. incompatible primes. But what is interesting for our purposes is that participants also gave higher *control* ratings for colours following action-compatible primes vs. colours following action-incompatible primes. This finding suggests that their judgements of control were based on feelings of fluency pertaining to the ease of the action selection process. In other words, the easier their actions were to perform in terms of not conflicting with a primed alternate response, the more they judged themselves to be in control over the effects of that action.

It is important to note that the judgements of control solicited in these types of studies may be sensitive to a range of cues pertaining to motor control that go beyond feelings of dis/fluency. Indeed, in a recent attempt to isolate the respective contributions of action-selection fluency and action-outcome monitoring to judgements of control, Sidarus et al. (2017) conducted a multi-study analysis of seven experimental studies investigating judgements of control under various conditions. In particular, the authors examined three cues: congruency between primes and action—i.e., the ease of action selection—the temporal interval between the action and its outcome— and the action outcome itself—i.e., the colour of the disk, dependent on the congruency between prime and action.

Interestingly, the authors found that the relative contribution of the two retrospective cues (action-outcome interval and outcome identity) to judgements of control was modulated by contextual information, including what the participants were instructed to attend to. What this finding suggests is that the agent's ongoing attention to various situational factors contributes to their judgements of control, a finding which fits well with a view of these judgements as forms of metacognitive monitoring and evaluation that are based on attending to certain cues that carry information about the success of one's control processes.

What all this suggests is that (i) skilled agents can use metacognitive judgements of performance to determine when to exert more cognitive control over aspects of their performance and (ii) even when agents are not consciously monitoring their actions, or engaged in explicit metacognition, a significant degree of implicit metacognitive monitoring is nonetheless taking place. This constitutes an important form of online control in skilled performance and helps to explain how it is that skilled agents monitor what they are doing in ways that do not result in the yips or other detriments to performance.

6. Metacognition and Flow

Central to the phenomenology of skill is a subjective experience that is known as 'flow'. This experience has been characterized in numerous ways, but it can be understood generally as "the subjective experience of engaging just-manageable challenges by tackling a series of goals, continuously processing feedback about progress, and adjusting action based on this feedback" (Nakamura and Csikszentmihalyi 2009, p. 90). The phenomenology of flow is multifaceted. As Shepherd (2021) recently discusses, researchers have identified at least nine dissociable components of flow, and there are several ways to think about how exactly they all hang together—the verdict still largely out about what is the best one.

Here I will focus on three of the most commonly discussed components of flow experience: (i) a sense of effortlessness accompanying one's actions, (ii) a merging of action and awareness, and

(iii) the subjective balance between abilities and task demands (also known as feelings of 'being in the zone'). All three, I conjecture, can be fruitfully understood as forms of metacognition.

Start with the sense of effortlessness. I suggest that this is underpinned by implicit metacognitive feelings of fluency as an action unfolds, and is also related to judgements of control. The more fluent action selection is, the more predictable are action outcomes, and the better able a skilled agent is to exert and feel control over their situation. Moreover, the type of implicit metacognitive monitoring underlying feelings of fluency can also be appealed to in order to account for "the merging of action and awareness" that is characteristic of flow, which is described as follows by Csizksentmihalyi (2014):

> A person in flow does not operate with a dualistic perspective: one is very aware of one's actions, but not of the awareness itself. […] The moment awareness is split so as to perceive the activity from "outside," the flow is interrupted. (138)

This merging of action and awareness can be readily explained if the monitoring in question is not carried out by the agent explicitly or deliberately and involves processes that are internal to action control itself, as I am suggesting here.

Higher degrees of fluency likely also contribute to higher levels of confidence with respect to one's overall performance, as reflected in the following testimony by a golfer experiencing a series of positive outcomes within a performance:

> "I was just confident in pretty much everything... It was kind of a feeling like "well there's not really too much in my way right now, everything's going my way," and I just felt like I can shoot the lights out... My swing was beginning to feel good and... I liked the holes coming up, I knew I could play well" (Swann et al. 2016, p. 17).

And this confidence, in turn, may contribute to the type of performance control that Swann et al. (2016) have termed "letting it happen", which involves the agent letting their actions unfold largely automatically and with little intervention from cognitive control, including explicit metacognition.

Finally, when it comes to the sense of being 'in the zone', I suggest that this is the result of explicit metacognitive judgements of performance. Recent experimental work supports this proposal. The results of a study by Vuorre & Metcalfe (2016) indicate that judgements of being in the zone show a different pattern of task sensitivity than judgements of control. Judgements of control are highest when a task is easy and decrease linearly as the task becomes more difficult. Judgements of 'being in the zone', by contrast, increase as the task becomes more difficult and peak at middle-values of difficulty when an agent's skills and task demands are balanced.

But what appears to be important here is not that an agent's skills and task demands *are* balanced, but that the agent perceives them to be. Thus, Kennedy et al. (2014) have tested out what they call the 'balance-plus-hypothesis, according to which 'in the zone' judgements are highest when the balance between task demand and ability is accompanied by *a metacognitive evaluation* of one's own performance. In particular, they hypothesized that "higher levels of zone may be experienced when perceived performance on a particular trial is high compared to when it is low" (p. 50), and this is indeed what the results of their study suggested.

Just as implicit metacognitive monitoring underlying the sense of effortlessness is plausibly associated with "letting things happen", I suggest that the explicit form of metacognition underlying the sense of being in the zone is associated with the type of control that Swann et al. (2017) call "making things happen", which often occurs in the context of so-called "clutch" performances.

Toner & Moran (2020) offer a useful characterization of this phenomenon as "an intentional process involving a conscious decision to increase the attentional resources that one devotes to performance. During this state, task execution continues to unfold in an automatic manner but the performer devotes additional cognitive resources to strategic control." This is precisely the type of shift in the interplay between cognitive and automatic control that metacognition is ideally suited guide.

An understanding of when to let things happen and when to make things happen is obviously essential to skilled action. I hope to have shown here how a focus on metacognition can help us see how this is achieved, and shed some light on aspects of the phenomenology of skilled action to boot (see Mylopoulos & Pacherie 2020 for further discussion and Bicknell 2020 for an additional take on the role of metacognition in skill).

7. Conclusion

In this chapter, I suggested that recent theorizing about skill is best understood as having taken a cognitive scientific turn, where the main debate concerns the extent to which cognitive control vs. automatic motor control processes contribute to skilled action control. I then motivated a cognitivist view of skilled action, according to which cognitive control plays a crucial role in skilled performance, alongside automatic motor routines. Finally, I argued that no cognitivist account is complete without considering the role of metacognition in skill, as it provides a form of meta-control that is essential to navigating the interplay between cognitive and automatic control, as well as an implicit form of monitoring over motor control processes that does not disrupt performance. I closed with some empirically-motivated conjectures regarding the relationship between metacognitive processes and the phenomenology of skill.

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