Mesh: cognition, body and environment in skilled action

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A central theme of embodied cognition research is the idea that cognition is grounded in the rich interaction processes by which individuals navigate the world – interaction processes that are deeply shaped by the physical structure of bodies and the environment. It is, moreover, often suggested that traditional cognitive science has neglected these interaction processes, and that properly taking them into account has profound conceptual consequences. For obvious reasons skill research and sport psychology are areas of prime interest for embodied cognition theory – advanced skills exemplify highly tuned, richly interactive human abilities. Recently we have proposed a theory of skill called *Mesh* (Christensen, Sutton & McIlwain, 2016), and at the kind invitation of the editor Max Cappuccio the original paper is reprinted here. In this new introduction we expand on the issues that *Mesh* tries to address and discuss some of the connections between *Mesh* and broader issues in embodied cognition and sport psychology.

One of our objectives in developing *Mesh* has been to articulate key concepts and issues in a way that opens them up to further investigation. *Mesh* takes a particular stance on skill learning but our feeling is that it is at least as important to further unpack the issues as it is to take a stance at this point. Skill theory must grapple with many of the most fundamental issues in cognitive science and in turn should be one of the primary arenas for theory in cognitive science, given that most human abilities involve skill to some degree. Yet skill theory has until recently been relatively neglected. The two most influential foundational theories remain Fitts & Posner (1967) and Dreyfus & Dreyfus (1986), with Ericsson (2006) providing an important alternative perspective. As valuable as these theories have been, given the complexity of the underlying issues and their importance there is surely scope for a broader and more elaborated body of theory. If we can enrich our conceptual resources, undertake a more critical analysis of intuitions and phenomenology, bring to bear recent developments in cognitive science, and develop a more comprehensive empirical picture, then new avenues of investigation should emerge and a much richer body of theory will become possible.

Intuitions and phenomenology are an important source of influence for theoretical and empirical researchers. This is especially clear in the case of the theories of Fitts & Posner and Dreyfus & Dreyfus, which present a qualitative picture of skill learning that is primarily based on intuitive phenomenology, but the influence can also manifest in less visible framing assumptions that shape experimental and theoretical work. The Fitts & Posner and Dreyfus theories depict skill learning as a progression from initial problem solving in the novice followed by a reduction in conscious cognitive control that culminates in full automaticity in the expert. A major reason for their appeal is because they resonate with common skill experiences and fit a widespread folk view of skill (Montero, 2016). Intuitive folk wisdom deserves careful scrutiny, however, and the 'mindless' view of skill phenomenology has in recent years been challenged by a number of authors – see e.g. Breivik (2007), Sutton (2007), Geeves et al. (2008), and Montero (2010).

The tension between 'mindless' and 'minded' interpretations of the phenomenology of skill played an important role in the development of *Mesh*, and we were in particular struck by inconsistencies in practitioners' lore and phenomenological reports. On the one hand, experts sometimes stress the way the body takes over as skill develops, and often express concern about 'overthinking' on the basis of their experience of the disruptive effects of certain kinds of reflection and explicit thought. On the other hand, experts often underline the need to adapt rapidly and appropriately to novel or challenging conditions, thinking on their feet and on the fly. Our ideas about 'applying intelligence to the reflexes' (Sutton et al., 2011; McIlwain & Sutton, 2014; Geeves et al., 2014) were a first attempt to resolve this apparent paradox, by shifting attention to the improvisatory roles of intelligent cognitive control in guiding and adjusting action, so that thinking itself is, for experts, rapid, fleet-footed, and context-sensitive, not effortful and lumbering. *Mesh* takes this further, systematically identifying forms of phenomenology associated with automaticity and cognitive control and developing a theory that can accommodate both. As we emphasize, however, this analysis is simply a preliminary step towards a systematic program of empirical investigation. For example, if we can reliably associate certain kinds of experience with automaticity or cognitive control then we may be able to employ questionnaires and interviews, administered shortly after real-world performances, as a way of investigating skill in its ecological context. If applied at many levels of skill and to a wide variety of skills this approach has the potential to yield a rich and nuanced empirical picture. Such an approach could contribute to a broader program of 'ecological' skill research that develops a clearer understanding of skill in its natural context.

One reason why a clearer ecological understanding of skill is important is because it can inform experimental research, including by providing a basis for assessing the ecological validity of experimental designs. Another of our goals in the development of *Mesh* was to articulate concerns that existing experimental research which appears to show skill automaticity (e.g., Beilock & Carr, 2001) suffers from problems of ecological validity. The nub of the issue is that this research has generally employed tasks that are easy for the expert participants. Skills in the real world are often difficult and performed in challenging conditions, especially at elite levels. This much is obvious – the contribution that *Mesh* makes in this regard is to provide an argument that this has significant implications. The nature of control may differ between easy and challenging conditions.

Our emphasis on the importance of studying cognition 'in the wild' is in keeping with prevalent themes of embodied cognition (Hutchins, 2010; Heft, 2013). But some approaches, such as ecological psychology, see this as requiring a strong set of theoretical commitments, whereas we don't think that such strong commitments are needed as a starting point for naturalistic investigation. Indeed, it is important not to prejudge central issues – a robust theoretical understanding of cognition in its natural context will only emerge as the result of extensive empirical investigation. The overarching framework for ecological skill research should be relatively minimal in order to allow for a diversity of approaches to flourish.

More specifically, the question of whether skill automates bears strongly on a repeatedly-invoked division between radical and moderate approaches to embodied cognition. On the standard view of the terrain,

so-called 'radical' approaches see a proper understanding of embodied, situated cognition as requiring a new conceptual framework that eschews the representational, information-processing framework of conventional cognitive science. 'Moderate' approaches believe that standard cognitive science can be extended to accommodate the phenomena of interest to embodied cognition (Shapiro, 2010). One of the key theoretical issues in this debate has centered on the idea that certain kinds of problems are 'representation-hungry' (Clark, 1997), and hence cannot be explained by non-representational frameworks such as dynamical systems theory. The question of whether skill automates can be thought of as a question as to whether advanced skills are representation hungry, or, perhaps, hungry for the kinds of representations employed by higher cognition according to mainstream cognitive psychology.

With regard to this issue, our approach is decidedly moderate, and we have formulated *Mesh* so that it draws on recent cognitive science research on cognitive control and automaticity to the greatest extent possible. Critics of representationalist cognitive science often associate it with a Fodorian picture in which control is performed by a central executive operating on amodal language-like representations. But cognitive neuroscience presents a very different picture in which there are multiple levels of control, including lower-level, fast perception-action loops and higher-level loops that integrate more widely and process more abstract information, with the loops functioning in intimate interaction (Fuster, 2004). Rather than there being a single, abstract language-like representational format, neuroscientific research points to progressive increases in abstraction in the flow from the sensory periphery (e.g. Binder & Desai, 2011). In our view it is plausible that mental representations are often model-based rather than language-like. The significance of this distinctive picture has not been widely appreciated, and *Mesh* attempts to elaborate some of its theoretical implications. On a more traditional dual process view cognitive processes are *either* automatic or controlled, but this hardly makes sense on the neuroscientific picture since most cognitive processes involve brain-wide interactions that include both automatic and controlled executive components.

In this picture overall control is distributed across higher and lower systems, which presents the challenge of understanding how they function in relation to each other. Anti-representationalists have often adopted the strong assumption that the problem of what to do can be resolved unambiguously based on immediate perceptual information – the expert just sees what to do (Dreyfus & Dreyfus, 1986). In a follow-up paper we argue that this is not the case – the complex, variable problems confronted by practitioners of elite skills present ambiguity that can be resolved only by means of higher levels of integration. It is necessary to track the unfolding structure of the performance situation, anticipate how it might unfold, and draw on background knowledge to interpret the situation.

In addition, though, on our account the cognitive processes employed in action control are reshaped during skill acquisition and come to be highly tuned to the demands of control. This means both that they reflect in increasingly intimate ways the structure of bodily interaction, and also that they incorporate increasingly rich representations *of* bodily interaction. Christensen et al. (2015) explore these issues in relation to sense of agency and sense of control, proposing new conceptualizations of these forms of

awareness in terms of awareness of control influences on a complex interaction process and awareness of performance state in relation to the limits of control (the 'performance envelope'). This account is based on investigation of mountain biking performance and illustrates the way that attention to the nature of skilled action in complex, real-world conditions can inform conceptions of cognitive representations and processes.

However, we dispute the idea that questions about representation should be the primary basis for understanding the significance of embodied cognition. In the development of embodied and distributed approaches to cognitive science, arguments for and against representations are distinct from arguments for or against individualism or internalism, the idea that (the vehicles of) cognitive processes and cognitive control are entirely brain-bound (Sutton, 2015). In our view, anti-individualism (in its different forms) is the most far-reaching and 'radical' development in the recent cognitive sciences, though the language of revolution is perhaps not entirely appropriate (Sutton, Harris, Keil, & Barnier, 2010). *Mesh* is representationalist but it tends to support anti-individualism and anti-internalism. By showing how cognition can be intimately structured for the demands of interaction it can help to illuminate the way that task control can be flexibly distributed across body and world, and between individuals, as well as across the brain.

To sum up, we want to reiterate that further opening up the issues that *Mesh* is trying to address is as important as the specific claims of the theory. There is a need for an enriched body of theory on skill that can (a) foster the development of a clearer picture of skill in its ecological context, (b) inform experimental work by contributing to ecologically valid designs and by filling out the theoretical space, (c) bring to bear related research in the cognitive sciences, and (d) furnish new conceptualizations of the context, experiences and mechanisms of skilled action. In turn, skill theory has the potential to inform many areas of cognitive science, not least the foundational questions that have concerned embodied cognition researchers.

A more concrete concern, however, is the question of what *Mesh* can specifically contribute to research on sporting and related skills. The short answer is that it begins to develop a systematic basis for addressing the idea that skills may involve both automaticity and cognitive control, and this can encourage new lines of investigation into the possible contributions of cognitive control to skills thought to be largely automatic. Toner, Montero and Moran (2014) argue that the approach may help to illuminate the nature and role of cognitive processes in training and online execution, such as the use of 'instructional nudges' to adjust performance. Toner, Montero and Moran (2015) argue that excessive automation of performance results in errors, and they develop a taxonomy of errors that can arise. Collins, Collins and Carson (2016) found that high level sport coaches showed metacognitive awareness of the advantages and disadvantages of intuitive versus more deliberative styles of decision making in a given context, allowing them to switch styles appropriately. They argue that this is consistent with *Mesh*, and in particular the idea that the athlete maintains an appropriate balance between cognitive and automatic aspects of control. Demos, Lisboa and Chaffin (2016) investigated flexibility of expression in

classical concert piano performance, finding evidence that cognitive control was employed at phrase boundaries and suggestions that it may have operated more continuously through phrases. Using a golf putting task Arsal, Eccles and Ericsson (2016) obtained results supporting three key claims made by both *Mesh* and Ericsson's theory, namely that experts should show greater awareness of performance than those with less experience, that increasing task challenge should result in greater cognitive control, and that cognitive control is often concerned with strategic aspects of performance. If performance does involve both cognitive and automatic components this has pedagogical implications, and Collins, Carson & Collins (2016) suggest that *Mesh* aligns with an approach developed in coach education called Cognitive Apprenticeship. This method encourages the learner to consciously articulate processes associated with performing complex skills, such as decisions involved in placing an anchor while rock climbing.

In short, *Mesh* resonates with and can help to inform some promising lines of investigation into sporting and other skills.

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