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Longer, Smaller, Faster Stronger: on skills and intelligence

One prominent feature of skill is the way in which it is acquired. That is, skills such as riding a bike, typing, or playing the piano are learned through practice and not through deliberation, reflection, or memorization alone. Philosophers have appreciated this fact about skill for ages[1] but despite a general recognition, no philosophical account of the exact connection between skill and practice has ever been forwarded. To make clear what I mean, compare the following questions: one might think that when we ask about the connection between practice and skill, we are asking a question about final causes. As such, when we ask, "what is learned through practice?" the obvious answer would be: "skill"! However, we might take the question to be of a different sort, to be a question about formal causes and, thus, to be something like the following: "how does practice change our behaviors such that they go from being awkward, unskilled actions to elegant, skilled performances?" If that's the question we are asking then what we want to know is *how* practice changes or impacts our behaviors. That is, we don't want to know what practice is for but we want to know what practice does.[2] It is this latter question that I will explore in this paper. Importantly, once the answer to that question becomes clear, we will be in a position to see why skilled performances, though automatic in many ways, cannot be thought of as mindless, brute or unintelligent. Rather, skilled actions are cognitive and minded almost all the way down.

This paper will proceed in four sections: in the first section I will defend the tight connection between practice and skill and then go on to make precise how we ought to construe the concept of practice. In the second section, I will suggest that practice contributes to skill by structuring and automatizing the motor routines constitutive of skilled actions. I will cite how this fact about skilled action has misled many philosophers to conclude that skills are mindless or bodily. In the third section of the paper, I will challenge this common misconception about automaticity by appealing to empirical evidence of motor chunking. This evidence reveals that there are two opposing processes involved in the automaticity of skilled action: one process that is largely associative, which I will call "concatenation" and the second, a controlled cognitive process, that I will call "segmentation". As a result of this evidence, we will be in a position to see clearly why skills are minded and intelligent not merely during their acquisition and not simply in virtue of their connection to intentional states, but, rather, in their very nature. I will end by reflecting on some

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[1] For instance, see Matt Stichter's (2007) defense of Aristotle's view of skill as "empiricist", i.e., holding that skills are learned through practice puts Aristotle's view in line with the accounts of Isocrates and the rhetoricians.

[2] See Aristotle *Physics* II 3 and *Metaphysics* V 2 for a discussion of the four causes.

theoretical reasons for why this is exactly what we should expect to be the case when it comes to skilled action.

I. Practice and Skill
It's no secret that when we set out to learn a new skill, the way in which we learn that skill is through practice. After all, we learn to dance the ballet by dancing ballet and we learn to play the piano by playing the piano. Of course, Aristotle made this point in the *Nichomachean Ethics* ages ago. Aristotle writes:

What we need to learn to do, we learn by doing; for example, we become builders by building, and lyre players by playing the lyre. So too we become just by doing just actions, temperate by doing temperate actions and courageous by courageous actions (NE 1033 a 32-b2).

This way of acquiring skills is to be contrasted with other methods of acquiring knowledge or expertise, such as through deliberation, memorization, or reflection. Notably, skills are special in that we learn them by performing them and not just by thinking about them. This is not to say that we don't also think a lot about the skills that we are learning to perform. It is only to say that, in addition to thinking, actual doing is required for skill acquisition.

It is, of course, also a familiar fact about skills that people often continue to practice their skills long after they have been acquired. That is, we humans have the strange habit of practicing a skill long after it is probable that we will be able to perform it to a reasonable degree of success in a reasonably large number of circumstances.[3] Just think, professional tennis players like Serena Williams and Roger Federer still practice on court for hours a day almost every day. And tennis is not an exceptional sport in this regard. When it comes to skill, practice is involved not only in skill acquisition but in the ongoing refinement of skill as well.

The connection between practice and skill has been widely appreciated by both philosophers and psychologists. So, for instance, when distinguishing habit from skill, that is, when distinguishing unintelligent, automatic behaviors from intelligent, fluid actions, Gilbert Ryle (1949) focuses on learning. He writes:

[A] mountaineer walking over ice-covered rocks in a high wind in the dark does not move his limbs by blind habit; he thinks what he is doing, he is ready for emergencies, he economises in effort, he makes tests and experiments; in short he walks with some degree of skill and judgment. If he makes a mistake, he is inclined not to repeat it, and if he finds a new trick effective he is inclined to continue to use it and to improve on it. He is concomitantly walking and teaching himself how to walk in conditions of this sort. It is of the essence of merely habitual practices that one performance is a replica of its predecessors. It is of the essence of intelligent practices that one performance is modified by its predecessors. The agent is still learning. (p.42)

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[3] See Millikan (2000), section 4.3, for a discussion of the ways in which abilities can succeed and be improved.

This passage highlights the requirement for attentive, intelligent, deliberate instantiations of behavior in the development of skilled action. What we should notice is that there are different ways of performing actions. And, importantly, simply executing or even repeatedly executing an action is not sufficient for performing it intelligently or for developing from it an intelligent capacity. Rather, an action has to be performed in a particular way in order for it to contribute to that action becoming or continuing to develop as a skill. Specifically, the action must be performed in such a way that the agent intentionally continues to learn while she is performing the action. This kind of engagement, I'll claim, is central to the characterization of practice. Barbara Montero (forthcoming) has made a similar point. She writes,

As the psychologist K. Anders Ericsson (1993) has documented, those who excel in a wide variety of fields have not only engaged in ten years of practice *(this is a reference to the ten year rule that was first forwarded as definitive of expertise in 1899 by Bryan and Hartner),* but have engaged in ten years of deliberate practice—that is, practice that involves not only doing the actions over and over again, as might be true of our daily activities like buttoning a shirt or driving to the office, but also involves working on aspects that are difficult and, after practice, analyzing one's own successes and failures. Beyond this, I would add that in order for someone to count as an expert under my stipulative definition, such individuals engage in ongoing practice (Montero, forthcoming).

As we can see, it is a fairly mainstream in sports psychology to hold that a very particular kind of intellectual engagement is involved in the acquisition and refinement of skilled actions. In fact, it seems that the intention to improve or at least to stabilize or maintain one's skills is essential to practice. After all, even those philosophers who characterize the pinnacle of expertise as ultimately mindless or bodily still acknowledge that deliberate, intentional, intelligent, minded activity is involved in practicing and developing skills in the first place. [4] That is, even philosophers who hold that skill, once acquired, is no longer best described as cognitive or intelligent, still accept that conscious, deliberate thought and effort are centrally implicated in practice.

To further precesify the notion of practice, I'd like to add that practice often involves not only the deliberate attempt to improve one's performance in general (for example, making a basket or landing a cartwheel or swimming faster), but also involves aiming to improve the technique by which one is able to perform the skilled action successfully. That is, during practice, skilled agents often attempt to improve not only their ends but also the means by which those ends are achieved. The point, then, is that practice often involves the means of a task becoming ends in themselves, at least temporarily. [5]

So, for example, a gymnast may practice her hand placement on the beam independently of the way in which that hand placement is related to successfully performing a back-handspring. That is, even though proper hand placement is

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[4] See, for instance, Anderson (1982) and Dreyfus & Dreyfus (1986).
[5] For a defense of this notion of practice and consideration of the significance for understanding human cognition see: Fridland (2013, 2014) and Fridland & Moore (2014).

essential for successfully performing a back-handspring on beam, during practice, the gymnast will practice proper hand placement as an independent task. I maintain that skills, very generally, have this kind of structure and that practicing a skill often involves the means, at least temporarily, becoming ends in themselves.[6] We should notice that performing an action attentively and deliberately should result in improvements. However, performing an action in the way specified here, such that the technique itself becomes the object of attention and deliberate effort narrows the scope of proper practice even further. Moreover, it does so in such a way that it is at the very least possible that only humans practice in the latter, more demanding manner.[7]

In this section, I've claimed that the intimate connection between skill and practice has been widely appreciated by both philosophers and psychologists. And, further, I've claimed that practice is commonly understood to be an explicitly intellectual or intelligent phenomenon. I've also maintained that in skill learning the goal of practice is often not only to successfully perform a task, but also to improve or refine the way or means by which the task is performed. I take it that, until now, I have not said anything particularly controversial.

II. Practice and Automaticity

Another claim that I take to be relatively uncontroversial is that actions become automatic as a result of practice. That is, as a result of practice, motor routines—the learned motor representations that ground the instantiation of complex action sequences—go from being slow, error-prone, and difficult to control to becoming fast, accurate, and transparent—i.e., not requiring deliberate, conscious attention or effort.[8] This fact about skilled actions is sometimes taken to entail that skills are bodily phenomena and not properly minded or cognitive ones. I take the conceptual move from automatic to mindless to be fundamentally flawed. I will present examples of a number of philosophers making this move below and present empirical evidence of why it is mistaken in section 3.

First, it is worth noting that the idea that skills become automatic as a result of practice is widely accepted by both philosophers and psychologists. Further, it is widely acknowledged that one of the main benefits of automaticity is that it alleviates an agent's cognitive burden. That is, it is commonly accepted that

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[6] This is an important point to recognize if we want to tie skill learning to human cognition, generally, and to imitation, in particular. This is because imitation is often thought to have the functional, evolutionary role of allowing humans to learn skills. And what the studies on imitation and especially on overimitation show clearly is that the humans have a particular obsession not only with the goals of a task (that is, humans not only emulate) but with the fine-grained detailed strategy with which a task if performed (i.e., they imitate). For more on this, see, for instance: Call, Carpenter & Tomasello; (2005); Fridland and Moore (2014); Horner & Whiten (2005); Over and Carpenter (2012); Tomasello 1996, 1999.

[7] See Fridland and Moore (2014) and Fridland (forthcoming b.) for a defense of the uniqueness of the technique-centered orientation to humans. See also Sterelny (2012) for more on the distinction between human and non-human primate skill learning.

[8] I don't take this to be a comprehensive list of features of automaticity. And, in fact, I don't think such a feature list is possible. I've argued so much in Fridland (forthcoming). Rather, I take it that I am pointing to several features of automaticity that are relevant to this discussion.

automatic behaviors do not require (or require much less of) the limited resources of executive-level attention and higher-order thought (e.g., Bo and Seidler (2009); Ericsson et al. (1980). As Beilock and colleagues (2002) write:

Current theories of skill acquisition and automaticity suggest…that well learned skill execution is 'automated'—controlled by procedural knowledge that requires little online attention & control and operates mainly outside working memory (p. 1211).

Moreover, because automatic motor routines can be executed without (or with relatively little) conscious effort or deliberate attention, the effort and attention that would be necessary for performing those actions can be dedicated to other aspects or features of a skill, performance, or situation. For example, compare the effort required when learning how to use chopsticks to the experience of eating confidently with them. Very generally, once a skill becomes automatic, one can focus one's energy on higher-order aspects of a performance, such as strategy, aesthetic qualities, or the dinner conversation. Additionally, because the cognitive load of acting non-automatically has been reduced, automatic actions can be executed in parallel with other tasks. Think of driving a car and flipping through radio stations at the same time or walking and texting. In fact, a resistance to dual-task interference is one of the hallmarks of automaticity.[9] Accordingly, as skills become automatic, they can also become more complex.

     The fact that skilled actions are in many respects automatic has led many philosophers of different stripes and with varying and often conflicting accounts to conclude, incorrectly, as I'll argue below, that skills are mindless or bodily. That is, falling into the trap of dichotomous thinking, philosophers often equate being automatic with being unintelligent.[10] As I've argued elsewhere:

       It is not rare in philosophy and psychology to see theorists fall into dichotomous
       thinking about mental phenomena. On one side of the dichotomy there are
       processes that I will label "unintelligent." These processes are thought to be unconscious,
       implicit, automatic, unintentional, involuntary, procedural, and non-cognitive.
       On the other side, there are "intelligent" processes that are conscious, explicit, controlled,
       intentional, voluntary, declarative, and cognitive. Often, if a process or behavior
       is characterized by one of the features from either of the above lists, the process or
       behavior is classified as falling under the category to which the feature belongs. For
       example, if a process is implicit this is usually considered sufficient for classifying
       it as "unintelligent" and for assuming that the remaining features that fall under the
       "unintelligent" grouping will apply to it as well. Accordingly, if a process or behavior
       is automatic, philosophers often consider it to be unintelligent (Fridland, forthcoming).

     In fact, many philosophers have explicitly stated that skilled actions are controlled by the body and not by the mind. So, for instance, even though Fred Dretske's (1998) view is much more subtle than the following quote suggests, he can still be found saying things like: "[I]n the case of all skilled actions, whether it be tying your shoelaces, playing a musical instrument, or dribbling a basketball – the

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[9] See, for instance: Logan, 1979; Posner and Snyder, 1975a/1975b.
[10] I don't mean to suggest that all philosophers fall into this trap. There are notable exceptions, especially by those who work on embodied cognition. But, still, the tendency is real."

mind goes elsewhere while the body performs." And John Searle asserts that "[R]epeated practice enables the body to take over" (1983, p.150). Further, in explicating a very different kind of view, Sutton and colleagues, critiquing Dreyfus's account of skill, writes: "Only when one is involved, and gets a lot of practice, will the body take over and do the rest. There is then neither thinking nor awareness, neither attention nor choice: at this level of fluid performance, "an expert's skill has become so much a part of him that he need be no more aware of it than he is of his own body" (2011, p. 89).

All of this is meant to indicate (not prove) that there seems to be some tendency among philosophers to think of automatic behaviors as mindless or mechanical, bodily phenomena.[11] As such, skills, even very impressive skills, because they run automatically, are not considered to be properly classified as cognitive or intelligent events. The idea is that even though during practice, skills are the objects of cognitive control, once a skill is acquired and becomes automatic, it no longer remains cognitive or intelligent. So, whereas during practice, that is, when an agent was a novice, her actions were minded, once she becomes skilled, they become mindless.

In the following section, I will argue that the conceptual move from automatic to unintelligent is mistaken. I will do this by appealing to empirical evidence, which indicates that automatic motor routines are fundamentally minded, cognitive, and intelligent in both their nature and structure.

Before moving on, however, I'd like to direct the reader's attention to some bizarre implications of the kind of view that most philosophers hold. First off, on the face of it, it should strike as backwards to think that the actions of an unskilled novice are more intelligent than the actions of an expert. After all, doesn't just the opposite seem to be true? Surely, at the very least, a theory of skill should be committed to the fact that the more skilled an agent, the more controlled, appropriate, flexible, and manipulable her actions are.[12] That is, skills are qualified by features that seem to be fundamental to intelligence, generally, despite the fact that they are automatic.[13], [14] In line with this understanding of skill, does it not also seem that predicates such as "clever" or "brilliant" have more business being ascribed to experts than to the novices? [15] And if this is so, shouldn't we take this to at least potentially tell us something about the cognitive or intelligent nature of skill?

Finally, even if one is unmoved by these general considerations, I expect that the empirical evidence concerning motor chunking that I will present below will

[11] See Fridland (forthcoming) for several examples of philosophers equating being automatic with being unintelligent.
[12] See Logan (1985) for more on skill, control and automaticity.
[13] See Fridland (2015) for more on the relationship between intelligence and learning, and more specifically, on the relationship between intelligence and flexibility, transferability, manipulability and appropriateness.
[14] See also Levy (2015) and Mandelbaum (2015) for more on the connection between flexibility and intelligence.
[15] See Fridland (2012) for an explicit argument for this view.

illustrate how automatic motor routines are importantly cognitive in both their nature and structure.

III. Motor Chunking and the Intelligence of Automatic Motor Routines

In the previous section, I claimed that because skilled behaviors are automatic, many philosophers have characterized them as mindless. In this section, by focusing on empirical research elucidating the underlying processes of automaticity, I'm going to make clear why the standard way of thinking about the automatic motor routines constitutive of skilled action is largely wrong. Specifically, by considering the nature of motor chunking, a process that is widely believed to underlie the automation of motor routines, I will highlight how a central part of being automatic remains very much cognitive, controlled, and intelligent. I will close by providing some theoretical reasons for why this is very much as it should be. That is, I will claim that the automatic processes involved in skill exhibit a flexibility, manipulability, and responsiveness to our goals and reasons, which requires that they remain cognitive and controlled. Moreover, I'll claim that this kind of flexibility and control cannot be achieved if automatic processes become large, fused, mindless motor programs.

To begin, motor chunking is the (unfortunately named) "process that facilitates movement production by combining motor elements into integrated units of behavior" (Wymbs et al. 2012, p. 936). These units or chunks are then stored and executed as unified wholes (Bo and Seidler, 2009; Kennerley et al., Sakai et al., 2003, 2004; Verwey and Eikelboom, 2003; Verwey et al., 2009; Verwey, 1994). The idea is that by combining individual elements into a single motor plan, we have the ability to store, access and execute integrated units in a way that substantially reduces our cognitive burden (Bo, Borza and Siedler, 2009; Ericsson et al., 1980). More precisely, we don't have to think of and execute each element in a sequence or series individually but, rather, once a routine has become automatic, we can store, access and implement a cluster of elements together. So, for example, whereas we would need to control 6 individual elements in a novel sequence, when those 6 elements are chunked into, e.g., 2 units of 3, we only need to control, access, and execute 2 elements. The same principle should apply to tasks that have several parts but not several individual elements, like riding a bike or doing a cartwheel. That is, this principle should apply not only to sequential learning but to skill learning in general.

Behaviourally, a motor chunk is identified by the execution of a quick succession of action elements preceded by a longer pause (Kennerley et al., 2004; Verwey and Eikelboom, 2003). So, using a simple example, if one had a series of elements such as the following: "A B C A B C" a typical way of chunking those elements would be like this: [ABC] [ABC]. The elements within brackets exhibit a strong connection to one another as evidenced by their execution in quick succession and the brackets and space in between indicates a chunk or unit break as evidenced behaviorally by a pause before the quick instantiation of elements inside the set or unit.

It's vital to see that the empirical evidence concerning motor chunking indicates this kind of unitization proceeds as a result of two different, likely hierarchical processes (Verwey, 2001; Hikosaka et al. 2002, 1999; Sakai, 2003;

Wymbs et al., 2012). That is, motor representations are transformed in different ways at different processing levels. And, for my purposes, it is crucial to notice that the processes are not only different but likely opposing. As Wymbs et al. (2012) describes these processes they are:

a. Concatenation: the formation of motor-motor associations between elements or sets of elements.
b. Segmentation: parsing of multiple contiguous elements into shorter action sets.

As I discuss each process and its function in facilitating motor chunking, it will become clear why getting clear on the details of chunking challenges our notion of automatic motor routines as mindless or bodily.

3a. Concatenation:
The first kind of process responsible for motor chunking is what I'll call, following Wymbs et al. (2012), concatenation. This is the process that I think naturally comes to mind when we think about automaticity. Concatenation is best thought of as an associative learning process where individual action elements are combined into wholes (Verwey, 2001). So, individual elements of an action sequence or task are fused or bound together into larger combined units. In brief, individual elements in a series develop stronger connections to the other elements in the sequence through the process of concatenation. Concatenation can be observed behaviorally in the faster execution of a sequence or series after practice.

In order to elucidate the nature of concatenation, I'll appeal to two distinct kinds of evidence: the first is direct fMRI evidence found during motor sequence learning and the second is evidence from individuals with motor learning disorders. Wymbs et al. (2012), using a cued sequence production task analyzed sequence learning using fMRI. What they found was that during the concatenation of motor elements, the occurrence of which was assessed behaviorally, there was increased activation in the basal ganglia. This result should be unsurprising since the basal ganglia has long been implicated in motor learning, especially in procedural learning and in the production of implicit, automatic, and habitual behaviors (Albin et al., 1989).

This is why it is thought that individuals with Parkinson's Disease (PD), a disease which involves deficits of dopamine uptake by the basal ganglia, have difficulty executing implicit, automatic actions (Trembley et al., 2010). And this is also why it is thought that individuals with basal ganglia damage, such as that caused by basal ganglia stroke, experience motor sequence learning deficits (Boyd et al., 2009). Both groups fail to automatize sequences of motor elements in the same way as healthy controls. Specifically, for this group of individuals, the normal strengthening of connections between action elements that develops during practice in healthy controls does not seem to take hold and, thus, prevents normal motor chunking. As such, PD patients and those who have experienced basal ganglia stroke experience difficulties acquiring learning new automatic routines and, at times, in executing old ones.

Importantly, for my purposes, neither patients with PD nor those with basal ganglia stroke seem to have any deficits when it comes to explicit knowledge of motor sequences (Boyd et al., 2009). That is, these patients have no more trouble recognizing or reporting the repeated patterns or sequences involved in a motor task than healthy individuals. As such, we can be fairly certain that the motor learning deficits of PD and basal ganglia stroke patients are not the result of a personal-level or executive-level, cognitive failures to learn or recognize the relevant sequence elements or their pattern of connection.

I think that concatenation is the kind of process that most philosophers and sports psychologists have in mind when they think of the automatization or chunking that occurs when individuals practice motor skills. And since it is this process that they is central to their thinking, it is unsurprising that they go on to characterize automatic motor routines as bodily or non-cognitive.

However, if concatenation was the only process involved in the automatization of motor routines then we'd expect to see the connection between all elements in a sequence increase to form a large single unit or motor plan. That is, if only concatenation were involved in the unitization of automatic motor routines then we should see an undifferentiated associative increase in the connection between all the motor elements in a motor sequence, at least until the relevant limit on working memory had been reached.[16] So, for example, if concatenation was alone responsible for motor learning, what we'd see if we started with a sequence like "A B C A B C" is a stronger connection between all the elements in the series, such that the entire succession of elements could be executed faster. We could represent such an increase in associative strength as follows: [ABCABC]. However, as I indicated above, in healthy individuals, motor chunking actually looks more like this: [ABC] [ABC].

As such, we can see that it is not the case that in healthy individuals, motor chunking is simply the result of a concatenation process. That is, it is not the case that motor chunking just manifests in a stronger, undifferentiated connection between all action elements equally. Rather, motor chunking manifests in a strong connection between a set of elements in an action sequence, and that set is separated from other sets of very well-integrated elements in a larger series. Importantly, the way that motor elements are arranged into groups often follows a logical pattern, when such a logical pattern exists in the sequence and can be gleaned by the learner. For example, repeating elements are grouped together and there is a break after the completion of the last element in a pattern that is repeated. This grouping, as I'll discuss below, is not simply the result of the limitations of working memory but, rather, an efficient strategy for structuring the sequence.

All of this to say that concatenation is only one part of the chunking process, which underlies the automatization of motor routines. Concatenation is an associative process where (1) the basal ganglia is critically involved as indicated by

[16] There is some controversy over how many elements can be stored in working memory. Almost everyone agrees that at least 3-5 elements can be stored in working memory (e.g., Bo & Siedler, 2009; Pammi et al., 2011) but recent studies suggest that working memory can store as many as 7 -10 (Kennerley et al., 2004; Sakai, 2003) elements and maybe more (Ericsson et al., 1980).

direct fMRI evidence and (2) the basal ganglia is an important site of implicit, procedural learning, which has little to do with personal-level executive function, as we know based on evidence of motor learning disorders such as those exhibited in PD and after basal ganglia stroke.

3b. Parsing:
The second process underlying motor chunking is a process that I'll call, also following Wymbs et al. (2012), parsing. This process is responsible for cutting action sequences into shorter segments. That is, parsing or segmentation works by breaking down longer sequences into smaller sets or units. Importantly, parsing appears to work in the opposite direction of concatenation, which fuses together individual elements into larger wholes.

　　　　Crucial for the purposes of this paper, the process of parsing seems not to be an associative process but an executive or control one (Pammi et al., 2012; Kennerley et al., 2004 Verwey et al., 2011; Verwey, 2010). This characterization of parsing is supported by two forms of empirical evidence: direct fMRI evidence observed during motor chunking and considerations based on motor learning deficits that are related to ageing and general cognitive decline.

　　　　First off, in an fMRI study of motor chunking during a cued sequence reaction task, Wymbs et al. (2012) found increased activity in the dorso-lateral prefrontal cortex in sequences that were easier to segment. That is, in sequences that had more natural, logical joints to parse and thus were more likely to be parsed, Wymbs et al. observed that that the prefrontal cortex was more active. This evidence suggests that the segmentation of sequences or series into units or sets is the result of cognitive or control processes. We can conclude this because the prefrontal cortex is the area of the brain widely acknowledged to be related to executive function. Moreover, upon reflection, this finding seems to make sense since the choice of how to parse a sequence should involve considerations about which ways of parsing it would be the most effective. In particular, these choices should involve consideration of the logical structure of the sequence or series since this will determine how one could best group the sequence such that it can be recalled and executed most efficiently.

　　　　Another reason to think that parsing involves executive areas is because we see deficits in motor chunking that arise in elderly populations (Verwey et al., 2011; Verwey, 2010). These deficits are thought to be related to overall cognitive decline in ageing. Moreover, these deficits are also related to decreased explicit knowledge, specifically, a decrease in the ability to recognize and report relevant patterns or elements in a sequence (Bo, Borza and Seidler, 2009; Verwey et al., 2011, Verwey, 2010). This is not to say that elderly individuals are incapable of motor learning altogether. In fact, the massively redundant motor system makes it the case that almost no injury or decline results in a complete inability to learn motorically. So, just as patients with basal ganglia stroke are able to improve and learn motor sequences to some extent (Boyd, 2009), elderly patients are also capable of some motor learning (Verwey, 2010). But, upon examination, it seems that what the elderly patients do is to learn associatively—that is, they concatenate exclusively. And so, after practice, elderly individuals show some improvement in their ability to

produce action sequences faster. However, they do not parse or segment sequences in the way that would produce characteristic chunks like those in healthy controls. All of this to say that cognitive decline seems connected to a decrease in the process of segmentation, crucial for producing the motor chunks characteristic of automaticity.

We can visualize parsing in the following way: we have a sequence with, say 6 elements, and that sequence is broken down or segmented into two sets. So, if the sequence is "A B C A B C" parsing would be responsible for segmenting the sequence into [A-B-C] [A-B-C] where the repeating pattern ABC is broken into two sets, each of which repeats the three-element pattern once. The dashes in between the letters are meant to indicate that parsing is not responsible for the increased connection between elements within the set or unit. Rather, it seems that concatenation is the process responsible for fusing those elements together.

Further, what's important to see is that parsing isn't just a stage in concatenation. That is, parsed segments aren't just waiting to be combined into larger motor units as practice continues. Rather, these units are robust. That is, even though their joints become harder to detect as a result of practice, with the introduction of a dual interference task, we see that the segments persist even after extensive practice of over 1000s of practice rounds (Verwey & Eikelboom, 2003). As such, we should conclude that motor routines retain their cognitive structure even after becoming automatic. That is, motor representations[17] do not simply become associative processes once they are automated but, instead, continue to be structured in a controlled way. All of this to say that it is not only in practice that a clear cognitive element is present in skill. In the last section of this essay, I will discuss why this finding should be unsurprising and, in fact, it is exactly what we should expect to be the case if we consider the nature and requirements of skill carefully.

What's more, we know that the parsing of motor chunks is not simply the result of capacity or load constraints. That is, it's not that a motor sequence is parsed simply because working memory or the motor buffer can't handle more elements in the sequence. And we know this because even sequences with as few as 4 elements tend to be parsed, in a robust way, into two sets of two elements. And it is universally accepted that 4 elements do not exceed the capacity limits of working memory (Miller, 1956; see Miyake and Shah, 1999 for an overview).

All of this to say that parsing is an essential part of motor chunking. Parsing is a control or cognitive process as we have seen indicated by both fMRI evidence and evidence from the abnormal motor learning of elderly patients due to cognitive decline. Importantly, parsing is involved in structuring the automatic motor routines according to the internal logical of the sequence and also according to the demands of the task. Further, parsing is not just a stage in concatenation. It is fundamental to the process of chunking.

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[17] It may be worth noting that I take representations to be informational states of a system. Sometimes representations are involved in carrying information in subpersonal, modular systems that are informationally encapsulated. In this way, representations are not necessarily conceptual or propositional and they are not necessarily responsive to conceptual, propositional content.

As such, we must accept that the automatization of motor routines that occurs in skill learning is at least partly cognitive. That is, both in the learning stages of automatizing motor routines and the later stages of executing and sustaining them, cognitive control is involved. From this we can conclude that the nature and structure of automatic motor routines is not simply associative, mindless or bodily, but very much cognitive. This is not to say that these processes remain necessarily conscious or are accessible to introspection, but it is a mistake to think that consciousness is required for cognition or mentality.[18] So, what we see is that the automaticity of motor routines is not simply a brute, bodily phenomenon but importantly controlled by higher-order cognitive functions.

3c. Parsing and Concatenation
Together then, the way that we can visualize chunking is as follows: we begin with a sequence such as " A B C A B C" and the sequence is concatenated such that the connections between individual elements become stronger. We might visualize that a series becomes strengthened through concatenation such that it looks like this: [ABCABC]. Simultaneously, the series is parsed into smaller sets. One natural way of parsing this series would be: [ABC] [ABC]. The elements inside the sets benefit from being fused together by the concatenation process and this explains why the chunked elements inside the set are executed in fast, quick succession. However, the sets retain robust joints, which explains the pauses before the quick execution of the elements in the set. It is likely the case that at a higher processing level the sets, treated as individual units, are also concatenated such that the pauses in between them become smaller and smaller (Sakai et al., 2003; Verwey, 1996)—but, importantly, the joints still remain structurally robust, as we can see through the addition of a dual-interference task. In the following section, I'll claim that if we reflect on the nature of skill, it should become clear that the reason that sets retain robust joints is so that they can be controlled, intervened upon and manipulated as is necessary for skilled action.
So, to conclude, we see that automaticity proceeds by two simultaneous processes: on one level we have sequences that are broken down or parsed into smaller units and on another level those units are combined or concatenated into larger representations. And, as we saw above, the parsing likely involves executive or control functions and the concatenation is likely a result of lower level associative processes.

4. Parsing & Concatenation: Theoretical considerations
In this section, I want to turn our attention to some theoretical considerations for why it should be unsurprising that the automatization of motor routines through motor chunking involves both associative and control processes.
Let's begin with a simple example of skill: bike riding.
The reason for concatenation, I take it, is easy to provide. It's what everyone naturally assumes about automaticity. That is, for reasons of efficiency of storage

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[18] See, for instance, Rosenthal (1986) and Chalmers (1995) for more on mentality and cognitive function without consciousness.

and execution, it's important for action sequences to be combined into larger units so that they require fewer cognitive resources to implement. Concatenation, it seems, is likely responsible for our capacity to fluidly, smoothly, and elegantly combine several tasks together. Concatenation allows us to move from one task to another without having to think explicitly about each consecutive task and its connection to other tasks. For example, concatenation would be responsible for our ability to pedal our feet in constant motion and lean into a curve and shift gears smoothly, and steer all at once. And maybe even to hold a conversation with a fellow rider or to navigate in an unfamiliar city, to boot.

The reason for parsing, however, I think is rather different. As opposed to reducing cognitive load, it seems to me that the parsing or segmentation of a sequence is required for the flexibility, manipulability, and capacity for easy adjustments and varied responses that is at the heart of skillful activity. For instance, to return to our example, the parsing of action parts is necessary to retain the ability, to, for example, slow down one's pedal strokes to the appropriate degree, let's say, when one notices that there is traffic on the road ahead or to lean into a curve, but maybe a little less than usual, because of another vehicle in the next lane. Parsing may also be responsible for one's ability to slow down to take a look at a new store front or to focus on keeping one's feet parallel to the ground, when trying to improve one's cycling posture. The idea is that keeping action joints robust allows us to make the relevant adjustments and interventions in a performance based on our specific goals and strategies. That is, if all action elements were fused together into wholes without joints then one would lose the easy ability to intervene on the skill as it is unfolding in the various relevant and context-sensitive ways that are characteristic of skill. In short, is the existence of joints that I am claiming allows for the flexibility of skill.

We might take these considerations about what is required for skilled action even further. Rather than starting with an individuated set of distinct elements, as is almost always done in the lab, we might think that what often happens with skill learning in the wild is that we start with a more or less undifferentiated movement—one that, through trial and error, we have gotten to achieve task success in some context or other—and then we break down that movement, that is, we parse or segment that movement into smaller parts. Those parts then become elements that we are able to control, manipulate, and adjust in a more and more flexible and controlled manner. That is, through practice, we insert joints into our skilled motor routines.

And it seems that if we look at skill acquisition and skill refinement from a developmental perspective, this is exactly what happens. That is, we just so happen to stumble on a successful solution to a problem and then, by performing the action over and over and over again, we develop the capacity to control the relevant temporal and spatial parameters of the action in a more and more fine-grained way. This control is necessary for successfully instantiating the task in multiple different but similar contexts.

For example, we can think of something as simple as learning to use a fork. At first, we can see children struggle to get the fork to their mouths without dropping their food along the way. Even if the food stays on the fork, they might not be able to

get it directly into their mouths but instead they bring the fork to their chin, cheek, or nose instead. But, as is well known, with time and practice, children turn into experts. They figure out how to balance different kinds of foods on their forks and to smoothly get the food directly into their mouths in ways that reflect a sensitivity to the different kinds of foods on the fork, the different size of bites, their different weights, etc. My suggestion is that we should conceptualize this process as follows: instead of learning each part of the fork to mouth task independently and then combining individual elements together, children seem to begin with one more or less undifferentiated movement and then come to break that large, clumsy movement down into a movement with smaller and smaller sections that they can then adjust and manipulate flexibly as needed. That is, they develop control by instituting action joints at the relevant points of an action.[19]

If this is the case, then our conception of the chunking process would go something like this: we start with a more or less large, undifferentiated, and thus cumbersome, clumsy movement and then we break that movement into segments— into smaller parts that we can exert control over. The process of concatenation would continue to be required in order to ensure that those segments are connected in such a way as to retain the flow, fluidity and smoothness that is characteristic of skilled action and, further, that when particular manipulation isn't required, the action can unfold in a straightforward way without intervention and without the need for attention or higher-order thought.

 What's important for my purposes is to see that when we frame things in this way, even after acquisition, automatic motor routines remain importantly cognitive. That is, we see that the cognition involved in skill is not simply relevant for the acquisition phase of skill, but is retained in the shape and structure of the automatic motor routines constitutive of skill. It stands to reason that if one continues to refine one's skills, that is, to practice them with the deliberate aim of improving at a task, then one would anticipate that actions would continue to be broken down into more and more fine-grained parts that are themselves concatenated but which can be executed successfully in more and more variable circumstances. If this were the case, then we would be able to explain why continued practice yields continued and expanded control and flexibility and not simply faster and more accurate but ultimately inflexible movements.

Further, this way of framing things may also give us an explanation of why variability in practice not only produces more efficient learning,[20] but why it is that experts often attempt to reduce the automaticity of their motor routines. As John Sutton writes:

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[19] A related question is whether non-human primates are capable of and/or inclined to engage in this kind of parsing of behavioral repertoires. Work by Byrne (2003) suggests the non-human primates represent complex behaviors as sequences or what they call behavioral programs but it isn't at this point known if non-human primates ever take those behavioral elements as intentional objects to refine, improve, or recombine, as humans do in practice and teaching. That is, if they function as genuine sequences. See Sterelny (2012) and Fridland (2014) for related considerations.
20 See, for instance: Hall & Magill, 1995; Lee, Magill, & Weeks, 1985; Moxley,1979; Schmidt, 1975; Schmidt & Bjork, 1992 for more or the effects of variability in practice on skill learning.

In many distinctive domains, elite practitioners specifically resist the kind of automation which Dreyfus ascribes to the highest levels of expertise, worrying that trusting the body alone to take over will lead to arrested development. Just as they challenge themselves constantly and deliberately in practice, they know that in performance they will be constantly opened up to new limits. As Rietveld argues, "every situation contains perturbing influences", with new affective influences always potentially altering our evaluations of significance. So expert performers precisely "counteract automaticity", because it limits their ability to make specific adjustments on the fly (2011, p. 95).

This would explain why practicing in a variety of circumstances and focusing on different aspects of one's technique at different times is so important for developing expertise. That is, if we think of segmentation as that process by which we achieve control over our motor skills—and we think of variability as the way in which we promote parsing or segmentation, or resist concatenation—then we see why variability is so important for skill. One way of putting this would be as follows: variability in practice is required to keep our skills from becoming habits.

Another relevant issue here connects parsing to teaching and demonstration. As I've explained, once the elements of a skill are parsed it becomes possible to treat them as intentional objects in their own right, objects to adjust, control, and improve. But, importantly, once they become the objects of thought they can also become the objects of transmission. Put simply, once I can think about the technique I employ in performing a skill, I can also draw someone else's attention to that technique. And, further, since I have control over the elements that compose the skill, I can demonstrate to someone else how to perform it correctly, potentially contrasting it in various subtle ways with mistakes or improper ways of instantiating the element or technique. That is, once skills are parsed, what becomes available to an agent is not only the capacity to control and improve them but to transmit them as well.[21]

Taken together, all of this should help us to see that the mindless conception of automatic motor routines is simply misguided. Rather, we should hold that cognition is involved both during the practice stage of skill acquisition and, also, guides the representation and implementation of automatic motor routines, after a skill is acquired. That is, cognitive control dictates the structure of our motor representations and our ability to manipulate and control those representations during skill refinement and execution.

So, it isn't simply that when it comes to skill, cognitive control is present at the level of strategy or high level planning, or at the level of, say, aesthetic expressiveness or even simply during the practice leading up to skill acquisition— but that intelligence is present in the actual representation and execution of automatic motor routines. That is, cognition has to be present in the automatic execution of skills if we are going to have control that is flexible, manipulable and responsive to our goals, reasons, and wills.[22]

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[21] For more on the connection between the technique-centered orientation, high-fidelity transmission of skills, and teaching, see Fridland (forthcoming b.).

[22] To put it provocatively: if we are to have dispositions that are going to track knowledge, that is, dispositions that will allow us to know what to do, when and where to do it and with how much, then

5. In defence of control

I have offered an explanation of parsing in terms of the control of skilled action. Specifically, I've suggested that skilled action instantiations needs robust joints or segments to remain flexible and manipulable.[23] However, this story is at odds with a popular, competing explanation. Verwey (2001), though agreeing that motor chunking occurs at two processing levels, interprets these two levels differently from the way I do. According to Verwey (2001), "a motor processor rapidly executes the tightly coupled elements within each chunk, and the cognitive processor prepares each chunk for the motor processor. In this case, the pauses are due to planning at a supraordinate cognitive level." (Wymbs et al., p.13). Specifically, Verwey claims that in a familiar, overlearned movement, " the cognitive processor…selects a single representation –a motor chunk—for the entire sequence which is subsequently read and executed by a dedicated motor processor" (p.71). As such, instead of being involved in the control and manipulation of the action, as I have suggested, according to Verwey, cognition is required for planning, which is accomplished through the representation of a familiar movement as a cluster or whole.

However, the empirical evidence does not support Verwey's explanation for two reasons: First off, if the cognitive aspect of skill was concerned with planning skilled behaviors by producing higher-order representations of action sequences then we would expect to see cognitive areas at work in concatenation. That is, if planning were responsible for combining action segments together, as concatenation seems to do, and if planning is a higher-order cognitive process then the fMRI evidence should show executive areas involved in concatenation of action elements. However, as I have reviewed above, this is not what we see. In fact, we see that concatenation seems largely to be an associative process. As such, it is unlikely that the cognition responsible for motor chunking is concerned with planning through the higher-order representation of actions sequences as wholes. Moreover, if it were the case that cognitive control was required for planning or preparing the motor segments stored in the motor processor then one would expect pauses in between segments to max out the capacity of working memory. However, this also seems not to be the case, as we regularly see chunks with as few as 2 elements (Verwey, 1996; Sakai, 2003; Pammi et al. 2012). Since the higher-order representation of action elements could easily represent more than 2 elements at a time, it remains plausible that the pauses in between chunks are not primarily due to planning or preparation. I have suggested above that the breaks in between motor chunks are best explained in terms of control, flexibility, manipulability and the easy adjustment of skills in light of changing goals and reasons. I maintain that such an explanation is able to do justice to the empirical evidence regarding motor chunking.

those dispositions themselves must be structured in an intelligent fashion. This is provocative relative to Stanley and Williamson's (2015) view of skill.

[23] See Shepherd (2014) for a similar way of conceptualising control as connected to flexible execution.

6. Conclusion:

To review, in the previous sections, I have argued that practice and skill are intimately related such that practice is responsible for automatizing our skilled actions. I have also argued that the fact that skilled actions are automatic has led some philosophers to misconstrue skill as mindless or bodily. In order to remedy this misconception, I have appealed to empirical evidence of motor chunking. Importantly, this evidence reveals that there are two opposing processes involved in the automaticity of skilled action: one process that is largely associative and another that is cognitive and controlled. This evidence demonstrates that skills are minded and intelligent in both their nature and structure. I have ended by presenting some theoretical reasons for why these findings are exactly what we should expect, if we reflect seriously on the character of skilled actions.

Before closing, I'd like to note that though my considerations here have been largely limited to issues regarding the nature of skill it should be clear that understanding the intelligence of motor skill has some relevant implications for neighboring fields. For instance, I've argued that automaticity is not mindless and I have pointed specifically to ways in which automatic motor routines retain their cognitive and controlled character after automation. If this way of thinking about motor chunking is correct then it seems that advocates of embodied cognition have additional resources for conceiving of the body as intelligent. That is, as opposed to thinking of the body or bodily action as uniformly intelligent or cognitive, the considerations I've provided in this paper can help to differentiate the intelligence of different bodily phenomena and specify both where those phenomena are intelligent and why we should think of them as such.

Finally, I've argued that automatic processes may retain their cognitive character even after becoming fast and fluid. This way of understanding automaticity has implications not only for a theory of skill but, more generally, for a theory of the mind. This is especially clear if we consider the dual-systems theory of cognitive processing. According to the dual systems theory, our mind is composed of two largely independent processing streams. System one is an ancient, automatic, fast, point-and-shoot system that implements fixed, inflexible heuristic rules or programs and system two, in contrast, which is evolutionarily recent, slow, deliberate and flexible (Gigerenzer, et al. (1999), Haidt (2001), Kahneman (2011), Greene (2014). If what I've said about skill is correct, and automatic processes can be both cognitive in nature and structure then there may be a way to reformulate our conception of the ancient, fast, system from one that is fixed to one that adjusts in a flexible yet constrained manner. That is, if automatic processes can be honed and refined through practice and training then it is at least possible that the automatic, fast, and fluid processing of system one is also responsive to training and practice such that it adjusts in various appropriate ways to the goals, intentions, and actions of agents. In this way, understanding the nature of skill and skill learning has broad implications for our understanding of cognition and cognitive processing at large. I hope this paper has shown why that is.

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