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Shaping One's Future Self – The Development of Deliberate Practice

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Abstract

Deliberate practice, here defined as the ability to self-initiate mental or physical repetition with the goal of future skill improvement, is an important, but long overlooked, adaptive advantage of future-oriented mental time travel. There is as yet no evidence that nonhuman animals engage in deliberate practice, suggesting that it evolved only over the last 6 million years. The oldest indication of deliberate practice is currently associated with Homo erectus. Its emergence would have allowed hominins to become increasingly able to flexibly specialize, that is to rapidly adapt skill sets to changing environments, and to increasingly take advantage of tools and teaching. The extensive variety of human skills today is to a large extent a function of this essential capacity, but little is known about its development. We conclude with a discussion of the cognitive capacities that may underlie the emergence of deliberate practice in children and present the first empirical attempts from our laboratory.

Keywords:

Skill learning, mental time travel, episodic foresight, teaching, expertise, skill diversity, human evolution, cumulative culture, cognitive development

Shaping One's Future Self – The Development of Deliberate Practice

What we hope ever to do with ease, we must learn first to do with diligence

- Samuel Johnson

A key adaptive advantage of future-oriented mental time travel is that it allows humans not only to shape and control the world of the future, but also to intentionally change their future selves. People can set out to acquire skills and knowledge, and so deliberately alter their future being - which in turn influences their chances of future survival and reproduction. One powerful way in which one can acquire capacities is through practice. Humans regularly spend thousands of hours practicing skills they (or others) believe to be worthwhile improving, and this is essential to any explanation of the extraordinary diversity of expertise that characterize human societies (Suddendorf, 2013a). Yet, surprisingly little research has examined the nature and development of deliberate practice.

Deliberate practice can be regarded as repeated actions driven by the goal to improve one's future capacities and, so defined, it presupposes the ability to think about oneself in the future. We can imagine future situations in which it would be beneficial for our future self to have certain skills (or detrimental if we did not have them), and so we plan and pursue courses of action that we hope will let us acquire and improve specific capacities to a desired level. This is typically effortful, involving prolonged repetitions of certain actions. It often benefits from careful monitoring of progress and selection of what precise aspect of the skill ought to be trained next, and tends to progress from a focus on copying a model to a focus on outcome (e.g., Ericsson, 2008; Rossano, 2003). Deliberate practice allows us to learn relatively simple skills, such as how to write a letter of the alphabet, and with dedication, enables us to master extremely complex skills such as the exquisite playing of a musical instrument.

Not all skills, however, require deliberate practice. Certain skills mature in a quasi-universal manner. Infants learn to walk and talk without having to deliberately set out with such a goal in mind. Some capacities are learned incidentally. For instance, children learn to calibrate complex movements in the wake of playing throwing games, but are engaging in the repetitive actions because they are enjoying them in the present moment, rather than because they are aiming to improve hand-eye-coordination. Of course, there can be many reasons why one might engage in repetitive actions that are beneficial for skill acquisition and these need not be mutually exclusive. We can deliberately engage in, say, regular games of football because we enjoy the activity, because it keeps us fit, as well as because we want to get better at the game.

Deliberate practice does not need to rely on external triggers, but can be autocued (e.g., Donald, 1999). Indeed, it has been argued to depend on conscious, voluntary control (Rossano, 2003). We can choose to spend time honing any number of skills, and individuals differ vastly in what they decide to pursue and how much time and effort they are willing to dedicate. Nonetheless, much practice behavior is instigated or guided by others. Parents and teachers employ diverse techniques to get children to practice and improve, whether or not they want to improve themselves (more on how teaching and practice are intertwined further below). The focus of this chapter, however, is on our powerful ability to self-initiate practice with the goal of improving our future skills in mind. Furthermore, although deliberate practice may be helpful in improving a diversity of capacities (e.g., memorizing information through verbal rehearsal), here we will focus on the acquisition of motor skills.

Learning Motor Skills

Repeated practice can lead to neuronal changes that allow individuals to accomplish motor tasks in a faster and more accurate manner. Motor skill learning is a multilayered process that appears to be hierarchically organized, comprising action selection and action execution processes (e.g., Diedrichsen & Kornysheva, 2015). Action selection refers to the task of comparing alternative response options and selecting the most appropriate one based on expected rewards, costs, and goals. Once initiated, the action execution processes control the coordinated muscle activity in a replicable spatial-temporal pattern. Learning can take place at the execution level, at the selection level, or at intermediate levels. A novel action sequence requires demanding and time-consuming action selection and execution processes that, with repeated practice, can become increasingly fast and automatized. Elementary movements can be bound into chunks and executed faster and more accurately than when individually triggered by action selection processes (Rosenbaum, 1983). Hierarchical encoding allows for great flexibility as it enables individuals to combine and recombine motor primitives to generate novel action sequences.

Research on the role of practice in motor learning has identified various factors that play a role such as the type of practice (e.g., Jeannerod, 1994), whether practice is massed or distributed (e.g., Lee & Genovese, 1989), sleep between practice sessions (e.g., Walker, 2009; Wilhelm, Metzkow-Mészàros, Knapp, & Born, 2012), and the timing, type, and frequency of feedback involved (e.g., Schmidt, 1991; Sidaway, Bates, Occhiogrosso, Schlagenhaufer, & Wilkes, 2012). There is some evidence, for instance, that self-initiated feedback is more effective than feedback controlled by others (Kaefer, Chiviacowsky, Meira Jr., & Tani, 2014; Post, Fairbrother, & Barros, 2011). Though it may be questioned whether specific findings from research on simple motor skills can be generalised to more complex skill learning (Wulf & Shea, 2002), feedback certainly allows one in general to monitor progress and adjust practice accordingly, such that one may focus on those components of a sequence that are not yet acquired to one’s satisfaction. Football players, for instance, may benefit from spending more time practicing kicks with their weaker foot than from spending equal time practicing with each foot (Coughlan, Williams, McRobert, & Ford, 2014).

Once elements are accomplished, they can intentionally be assembled into novel sequences. Though motor skills are generally regarded as part of procedural control systems, deliberately engaging in such practice behavior demonstrates that declarative, even episodic, processes can direct and shape its development. Although debates about the relationship between foresight and episodic and semantic processes have long featured prominently (e.g., Martin-Ordas, Atance, & Caza, 2014), the effect foresight can have on procedural processes has been largely overlooked in the mental time travel literature. Yet, only through imaging a future self with improved skills may we be able to motivate, plan, and execute the honing of skills through deliberate practice.

Indeed, we can even choose to practice through deliberate mental simulation alone, rather than repeating actions physically, and still our motor skills can improve as a result (e.g., Cahn, 2008; Feltz & Landers, 1983; Zimmermann-Schlatter, Schuster, Puhan, Siekierka, & Steurer, 2008). Without immediate reinforcers, practicing, whether mentally or physically, is effortful and costly (at least in terms of opportunity). It therefore requires motivation derived from a commitment to the cause, even in the face of more immediately rewarding temptations. Indeed, it has been argued that to achieve outstanding expertise – consistently performing at superior levels in a domain – one has to engage in years of deliberate effort aimed at improving performance (e.g., Ericsson, 2008).

Mastery of Complex Skills

Unsurprisingly, there has been considerable research on how people acquire expert performance levels in complex skills associated with desirable arts, crafts, and professions. Much of this research has suggested that deliberate practice is the most important factor in determining expertise. Ericsson and colleagues (1993) championed this idea and proposed that individual differences in performance across many different domains can largely be accounted for by differential amounts of past and present practice. They define deliberate practice much more narrowly than we do here, limiting it to highly structured activities that were designed for the express purpose of improving performance through feedback, and that are demanding and not inherently enjoyable[1]. Exceptional skills are proposed to be the result of very long periods of deliberate practice, and that the amount of time spent on this is strongly and monotonically related to performance. In support of these assertions they report, for instance, that highly skilled musicians practiced for longer and had accumulated more practice hours over their lifetime than musicians of lesser skill. Expert violinists and pianists had accumulated on average over 10000 hours of deliberate practice.

With large amounts of practice, motor skills develop gradually from sensory-driven responses to integrated patterns of behavior relying on anticipation. This is associated with changes in the structural and functional organization of cortical motor areas (Dayan & Cohen, 2011). For instance, the volume of M1 and of premotor areas is larger in professional musicians compared to amateurs or non-musicians (Gaser & Schlaug, 2003) and the relevant sensory and motor representations performing body parts are enlarged in professional musicians (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995).

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[1] Others argue that deliberate practice further requires knowledge of the correct mechanisms involved (Colvin, 2008). We maintain that engaging in repeated actions with the goal of achieving a change in skill levels qualifies as deliberate practice, even if the mechanisms involved are not quite understood, or the activity is enjoyable.

While Ericsson and colleagues (1993) concede that other factors such as parental support and the age a person begins practicing are related to expertise, they assert that the role of these factors is fully mediated by deliberate practice. This view has garnered considerable support (e.g., Ericsson, 2008), and has been popularized in many books (e.g., Colvin, 2008; Coyle, 2009; Levitin, 2007; Shenk, 2010). Part of its popular appeal, no doubt, derives from the implication that anyone can become brilliant at whatever they would like to, as long as they put in the requisite hard work.

Alas, as many critics have pointed out, this is simply not the case (e.g., Sternberg, 1996). Many people fail to reach expert levels in spite of copious amounts of practice and comparable levels of elite expertise can be achieved with different amounts of effort (see Baker, Côté, & Deakin, 2005; Campitelli & Gobet, 2011; Hambrick et al., 2014; Hodges, Kerr, Starkes, Weir, & Nananidou, 2004; Macnamara, Hambrick, & Oswald, 2014). Studies suggest that, although deliberate practice is necessary, it is not sufficient to explain individual differences in performance. Additional factors such as starting age (Gobet & Campitelli, 2007), working memory capacity (Meinz & Hambrick, 2010), and inheritance (Hambrick & Tucker-Drob, 2015), also contribute to the development of exceptional expertise. Hambrick and Tucker-Drob (2015), for instance, found genetic effects on musical accomplishment in 800 pairs of twins, with a quarter of this explained by genetic effects on music practice. A recent meta-analysis on studies on chess and music found that about one third of the reliable variance in performance in both of these areas of expertise could be explained by deliberate practice (Hambrick et al., 2014).

Ericsson (2014) retorted by arguing that data on large samples of beginners may not be extrapolated to samples of elite performers. However, there are also data on top performers that question his claim about the supremacy of deliberate practice. For instance, Hornig, Aust, and Güllich (2014) found that the most successful professional football (soccer) players did not engage in more organized training practice, but in more non-organized football in childhood and more engagement in other sports in adolescence than other footballers, suggesting that incidental rather than deliberate practice was critical to their outstanding success. But be that as it may, here we are not so much interested in how individuals achieve the most outstanding performance levels in one specific field, but rather in how virtually all humans achieve some success in a variety of areas through deliberate practice. The bottom line is that what these studies have in common is that deliberate practice is an important factor in honing one's skills.

The Nature of Deliberate Practice

We want to examine the most fundamental capacity that allows humans to have a go at becoming an expert, whether they succeed or not. People regularly employ deliberate practice to acquire any number of mundane skills, from tying one's shoelaces to learning a particular dance, and this allows humans to adapt their skills to their individual desires and anticipated demands of future situations. It enables people to acquire any number of different skills and gives human groups supreme diversity in skill patterns.

Other animals also learn skills through practice. Mammalian play typically involves repetitive actions that resemble real fight, hunt, or flight patterns, and as such improve critical survival skills – natural selection favoring those who acquired better skills when the serious struggle for existence arrives. However, Donald (1999) argued that nonhuman animals do not spontaneously rehearse and refine their movement patterns. We know of no obvious evidence that other animals deliberately set out to improve particular future skills. Nor do we know of evidence for any of the consequences of having such a capacity. For instance, there does not appear to be a great diversity of skills in groups of the same species that could be attributed to differential deliberate practice histories. But we need to be cautious here, as this perception may reflect absence of evidence rather than evidence of absence. We cannot rule out that a young cat really sets out to become a better hunter when it repeatedly play-pounces on a fluff ball. And if one does not demand that deliberate practice requires the goal of future skill improvement, then various cases for animal “deliberate” practice may be made (Helton, 2005, 2008).

However, given that, according to our definition, thinking about future skill improvement is essential, a capacity for mental time travel is a prerequisite for deliberate practice. Without such a capacity, organisms may not be mentally confronted with the problems of future skills. The claim that mental time travel into the future is a distinctly human capacity (Suddendorf & Corballis, 1997; Suddendorf & Corballis, 2007) continues to have some currency, even though it has been challenged by a range of studies over the last two decades. Purported evidence comes from studies in which animals appear to take future hunger or thirst into account, for instance, by caching food (Correia, Dickinson, & Clayton, 2007; Naqshbandi & Roberts, 2006; Raby, Alexis, Dickinson, & Clayton, 2007), and from studies in which apes secure tools for future use (Mulcahy & Call, 2006; Osvath, 2009; Osvath & Osvath, 2008). However, these studies have been criticized and alternative explanations have been put forward (e.g., Suddendorf, 2006; Suddendorf & Corballis, 2008). The most recent challenge comes from work on hippocampal place cells in rats, whose activity suggest that the animals trace paths in a maze even when they are not in it (e.g., Gupta, van der Meer, Touretzky, & Redish, 2010), leading one of the original proponents of the uniqueness claim to change his mind (Corballis, 2013; but also see Suddendorf, 2013b).

Even if one takes this available evidence at face value, and we are not able to review it here, none of the limited number of cases made point to flexible, long-term foresight in non-human animals. Consider, for instance, the capacity to delay gratification (Mischel & Metzner, 1962). When given the choice between a small reward now and a larger reward later, our closest animal relatives, the great apes, can wait much longer than most other animals – but they still only wait for a few minutes (Beran, 2002; Dufour, Pelé, Sterck, & Thierry, 2007; Rosati, Stevens, Hare, & Hauser, 2007). Non-human animal foresight may be severely limited for a number of reasons (Suddendorf & Corballis, 2007). But putting skeptical critiques to one side, the evidence suggests apes may consider events hours, at the very best, a day in advance (e.g., Janmaat, Polansky, Ban, & Boesch, 2014; Mulcahy & Call, 2006). Deliberate practice for future skill acquisition, however, is by its very nature a long-term endeavour that often only leads to expertise days, weeks, or even years later.

Without being able to foresee the remote future and the desirability of relevant future skills, one may not be able to derive and follow a long-term plan towards changing one's capacities through deliberate practice. Immediate rewards may lead to behavior that improves skills, and human trainers can deliberately use standard conditioning techniques to shape diverse expert animal performances, such as turning dogs into herders, guards, hunters, helpers, retrievers, or drug detectors. However, in the absence of such immediate reinforcement, non-human animals may not autocue repeated actions to improve their skills. Humans, on the other hand, willingly forego present rewards in order to follow dreams of future accomplishment. As we saw, many spend thousands of hours honing their skills. This begs the question when this peculiar trait became part of our ancestries' repertoire?

Though we cannot directly examine deliberate practice in ancient hominins, there are some clues in the archaeological record that are suggestive. It has been argued that the earliest hard evidence for mental time travel into the future comes from *Homo erectus* some 1.8 million years ago: Acheulean tools (e.g., Suddendorf & Corballis, 2007). This tool set includes symmetrical tools such as bifacial handaxes and cleavers. Production of these tools requires considerable knowledge about rocks and skill at working them. Handaxes are handy tear-dropped shaped tools that have many potential uses, and represent perhaps the most enduringly popular tools ever made: they were manufactured for over a million years. At some sites, such as at the site of Olorgesailie in Kenya, the ground is still littered with them. This indicates that *Homo erectus* may have been practicing manufacture because they were making new tools even though plenty of useable tools were around them (Rossano, 2003). Acheulean tools are complex to produce but were made in a uniform manner, suggesting that they were made according to a deliberate plan. Furthermore, in addition to their manufacture, tool use indicates foresight because there is evidence that *Homo erectus* carried these tools to put them to use repeatedly (e.g., Hallos, 2005). So *Homo erectus* was likely making them with the future in mind and spent considerable amounts of time learning how to make them properly. We therefore suggest that they probably had the capacity to practice deliberately (cf., Rossano, 2003). Indeed, it is difficult to imagine that they could have become proficient at making these tools in any other way.

This is not to say that each individual learned how to make bifaces independently. In fact, the uniformity of the tools strongly suggests that the method was passed on from one generation to the next through social learning. Imitation and teaching are usually hailed as the two pillars of cultural transmission, our second inheritance system, allowing information to be passed on either with the intent of the knowledgeable or the ignorant (e.g., Whiten, 2005). A recent study suggests that already the making of earlier Oldowan tools may have been fostered by instruction (Morgan et al., 2015; though also see Balter, 2015). But even when one has observed how the tool is made, or been instructed on how to do it, ultimately one needs to practice the behavior repeatedly to train the motor skills at the selection and execution levels.

This need not mean that *Homo erectus* could already draw on all the hallmarks of modern human culture. One peculiar aspect of the Acheulean tool tradition is that it changed so little for over a million years. There is no evidence of what has been called the ratchet effect (e.g., Tomasello, 1999) through which individuals built upon the inventions of others over time. This effect has long been considered central to distinguishing modern human cumulative culture from non-human social traditions (Dennett, 1995; Sterelny, 2003; Tomasello, 1999). By retaining previous inventions with high accuracy, new generations can draw on the accumulated wisdom of those who went before. Consequently, a lot of recent research has focussed on the importance of "over-imitation" (e.g., Horner & Whiten, 2005; Nielsen, 2006; Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009) and the role of teaching (e.g., Hoppitt et al., 2008).

Yet, transfer of information is only adaptive when someone has something useful to transfer, and inventions worth retaining are not just single ideas or designs that individuals stumbled upon. To make an invention work, one typically has to master novel skills. For instance, the invention of weapons that can hurt at a distance are only useful in so far as one can become proficient enough to use them effectively (many involve acquisition of complex skills, as one can easily demonstrate to oneself by practicing them – you may have tried a bow and arrow, for instance). Through deliberate practice, these skills can be honed and, only once mastered, are the tools beneficial. A spear-thrower is only better than a thrown spear if one can acquire the motor skills to use this powerful tool effectively. And by the same token, bow and arrow are only advantageous over a spear-thrower when one has sufficiently mastered this weapon. Incidentally, chimpanzees may make spears and thrust them into a tree hollow to kill a bushbaby (Pruetz & Bertolani, 2007), but we know of no observation that they have practiced thrusting, let alone aimed throwing with this tool. Without a capacity for deliberate practice they could not benefit from the invention of a spear thrower.

Deliberate practice is closely linked to transmission mechanisms. Learning from others, whether via imitation or teaching, often involves deliberate practice. Observation and practice can powerfully combine in motor skill learning (e.g., Wulf, Shea, & Lewthwaite, 2010). And in a sense, deliberate practice is teaching oneself rather than others. Teaching oneself and observing progress in self and others, in turn, can provide insights into how best to teach others. Indeed, as we noted above, teaching others often involves guided practice and instructions on how to go about deliberate practice. Teaching and deliberate practice are intricately linked and arguably represent two sides of the same coin (Premack, 2007). Both are flexible tools we employ to shape our own and others' behavior in deliberate ways.

Acquisition and transmission of skills is essential to human cultural learning and appear only to exist as functional analogues in other animals. Some species, including meerkats and ants, can be said to engage in functional teaching in the sense that they will modify their behavior in a way that aids another individual to acquire knowledge or skills without obtaining an immediate benefit themselves (Caro & Hauser, 1992; Hoppitt et al., 2008). There is no sign, however, that teaching in non-human animals is a deliberate, flexible act, where the teacher plans the acquisition of future knowledge (Premack, 2007). Likewise, cases may be made for functional or incidental practice in some non-human animals, but as yet, there appears to be no sign of deliberate practice (Suddendorf, 2013a).

With the emergence of deliberate practice and teaching, our ancestors became increasingly capable to *flexibly specialize*. That is, instead of being a *generalist* or a *specialist* species adapted to specific environmental challenges, humans have the generalist capacity to rapidly (i.e., within a generation) specialize to changing demands. We can train ourselves to become diverse experts, specializing in what is needed at present and future points in time. This makes us extremely adaptable (and, of course, we have also adapted our environment increasingly to our future needs). Cooperative groups with the flexibility to create complementary skills as required would no doubt have out-competed others. Given how much time is involved in becoming a master in certain skills, it is clear that individuals cannot achieve elite levels in all, or even in very many, domains. However, each individual does seem to have the flexible capacity for deliberate practice and, within the constraint of their natural talent, can therefore become competent in a selection of a great variety of skills. In this way, humans could flexibly open up new niches. More research is needed on how flexible specialization evolved, and how cultural groups increasingly used cooperative teaching and deliberate practice to establish a successful mix of expertise.

What is clear, though, is that deliberate practice is important for the extensive variety of human skills we see today. Without it, we would not have the technology, civilization, and colourful diversity that we take for granted - and that we continue to build on for the future (Suddendorf, 2013a). It is therefore important, we argue, that more research is devoted to understanding this corollary of mental time travel into the future. For a comprehensive understanding of deliberate practice, we need to find out a lot more about its evolution, function, mechanisms, and development (c.f. Tinbergen, 1963). When exactly did it first evolve and in what contexts (just because stone tools survive the test of time does not mean the capacity emerged in that context)? What were its original functions? What are the neurological, cognitive and social mechanisms of deliberate practice? And how does the capacity develop in children? Here, for the remainder of this essay, we will focus on this last question.

The Development of Deliberate Practice

When do children start to engage in repeated action with the goal of improving their future skills? As already noted, to conceive of the goal to improve one's future performance levels, one has to be able to think about future situations in the first place. It is hence appropriate to first consider what is currently known about the development of mental time travel into the future. Children also need to have some appreciation of the link between practice and skill acquisition to pursue this goal. Further factors may play important roles in determining whether a child actually engages in deliberate practice, such as executive capacities necessary to maintain practice behaviors in the face of more immediate urges and temptations. We will discuss the development of these capacities before describing a first study directly aimed at examining deliberate practice in children.

The development of mental time travel into the future, or episodic foresight, has been of interest to researchers for almost 20 years (Atance & O'Neill, 2001; Suddendorf & Corballis, 1997), but the last few years have witnessed a considerable increase in studies (e.g., McCormack & Atance, 2011; Suddendorf & Moore, 2011). The simplest way of examining children's thinking about the future is to document their future-direct vocabulary (e.g., Busby Grant & Suddendorf, 2010; Harner, 1975), and to directly ask them (e.g., Friedman, 2005; Hudson, Shapiro, & Sosa, 1995). When questioned about events that will happen tomorrow or about plans for hypothetical future events, 3-year-olds are already capable of reporting some basic information, but older pre-schoolers provide significantly more events and details (Busby Grant & Suddendorf, 2005; Hayne, Gross, McNamee, Fitzgibbon, & Tustin, 2011; Suddendorf, 2010; Quon & Atance, 2010). Verbal reports may be misleading, however, because children may understand without having the means of expression, and they may use words appropriately without properly understanding their meaning (e.g., Lyon & Flavell, 1994). Thus, paradigms focussing on future-oriented behavior have been called for (Suddendorf & Busby, 2005).

Fortunately, the results of behavioral tasks are largely in line with the verbal evidence (see Suddendorf & Redshaw, 2013, for a review). One recent study, for instance, carefully followed strict criteria to rule out alternative explanations for children's behavior and found that 4-year-olds, though not 3-year-olds, were able to remember a novel past problem sufficiently enough to prepare appropriately for its future solution by securing an appropriate tool at a different time and place (Suddendorf, Nielsen, & von Gehlen, 2011; see also Atance, Louw, & Clayton, 2015; Payne, Taylor, Hayne, & Scarf, 2014; Redshaw & Suddendorf, 2013; Scarf, Gross, Colombo, & Hayne, 2013). In these tasks, children were presented with problems in one room, and later given the opportunity in another room to obtain tools for the potential future solution upon return to the first room. As we will see further below, one can adapt this basic paradigm to let children select a behavior to practice and so to give them an opportunity to carry potentially improved skills (rather than tools) back to the first room.

Although a major shift occurs during the preschool years, children's capacity to reason about the future and prudently guide their behavior continues to develop throughout childhood (Lagattuta, 2014; Suddendorf & Redshaw, 2013). One reason for this is that future-directed mental time travel is not an isolated module but depends on a range of components that tend to develop at quite diverse rates. Working memory capacity, for instance, an essential component for staging mental simulations (Suddendorf & Corballis, 2007), increases linearly between the ages of 4 and 11 (Alloway, Gathercole, & Pickering, 2006). Whereas other components, such as recursive capacities, which are, for instance, necessary for embedding elements of scenarios into larger narratives (Suddendorf & Corballis, 2007), emerge much more rapidly around the end of the preschool years (e.g., Corballis, 2014; Wells, 1985). Together, the developmental pattern of the various components enable distinct capacities and limits for children's episodic foresight (Suddendorf & Redshaw, 2013). Next we will briefly review the development of some of those purported components that may influence the capacity for deliberate practice not only via their effects on mental time travel, but also more directly.

Episodic memory is intimately linked in mind and brain to episodic foresight (e.g., Dudai & Carruthers, 2005; Klein, 2013; Schacter & Addis, 2007; Suddendorf & Corballis, 1997; Szpunar, Watson, & McDermott, 2007). There are commonalities also in their development, such that there are links, for instance, between children's capacity to report events from yesterday and tomorrow (e.g., Busby Grant & Suddendorf, 2005). Episodic memory provides a database from which children can construct future events by combining and recombining basic elements (Schacter & Addis, 2007; Suddendorf & Corballis, 2007). This is also critical for deliberate practice, in that a child who remembers a past situation in which performance was poor may be able to imagine a future scenario in which it is better, motivating skill acquisition through deliberate practice. By around 5 years of age, children have a robust understanding and expectation that a negative experience from the past is likely to reoccur (Lagattuta, 2007). Remembering what worked and what did not work in previous attempts is also critical to monitoring and fine-tuning effective practice. The development of episodic memory may be traced to the earliest declarative memories of toddlers as evident in deferred imitation tasks (e.g., Barr, Dowden, & Hayne, 1996; Herbert, Gross, & Hayne, 2007; Meltzoff, 1988) and matures into more coherent accounts of past events over the preschool years (Bauer, 2007; Hayne et al., 2011; Levine, 2004; Suddendorf & Corballis, 1997).

To drive deliberate practice, one has to do more than re-experience past events, however. One must also imagine and compare alternative situations. Through entertaining thoughts on what could have happened instead, and with this, feeling regret for not having been better-prepared in the past (e.g., Weisberg & Beck, 2010), one may deliberately practice for more desirable outcomes in the future. Similarly, by simulating what would happen if one did and if one did not have a particular skill at a future occasion, one can create motivation to practice. Counterfactual thinking may emerge around age three to four (Harris, German, & Mills, 1996), though some researchers argue it may emerge only as late as around age six (Rafetseder, Cristi-Vargas, & Perner, 2010; Rafetseder & Perner, 2010). The case for late development is in line with research that has found children represent multiple potential outcomes of a single event only from around that age (Beck, Robinson, Carroll, & Apperly, 2006). To stage and compare alternative mental scenarios, one may need considerable working memory capacity, which, as we saw earlier, only expands gradually between age 4 and 11.

To drive deliberate practice, one may also need some level of theory of mind. After all, one needs to evaluate how one will feel in different future situations and one needs some understanding of how feelings, skills, and knowledge can change. Theory of mind has long been linked to mental time travel (Moore & Lemmon, 2001; Suddendorf & Corballis, 1997; but see Hanson, Atance, & Paluck, 2014). Indeed, William Hazlitt already observed that "The imagination…must carry me out of myself into the feelings of others by one and the same process by which I am thrown forward as it were into my future being, and interested in it" (Hazlitt, 1805, p. 1). The findings of extensive research in recent years suggest that theory of mind develops gradually and through specific stages over the preschool years (e.g., Peterson, Wellman, & Slaughter, 2012; Shahaeian, Peterson, Slaughter, & Wellman, 2011; Wellman & Liu, 2004). A critical step in this is generally considered to be the understanding of false beliefs around age 3 to 4 (e.g., Perner, 1991; Wellman, Cross, & Watson, 2001), as this is thought to demonstrate a representational understanding of mind. That is, at this stage, children can metarepresent how others (and oneself) represent the world (e.g., Perner, 1991). This allows children to reflect on the relation between representations and what they represent – including the fact that a representation may misrepresent the world (e.g., Wimmer & Perner, 1983). This reflection is essential for assessing one's own cognitive abilities and processes (Schneider & Lockl, 2008; Suddendorf, 2013a).

From around the time children understand false beliefs in others, they also attribute former false beliefs to self (Gopnik & Astington, 1988), they begin to appreciate how perception can lead to knowledge (e.g., Gopnik & Graf, 1988; Perner & Ruffman, 1995), and recognize that they have not always known what in fact they have just learned today (e.g., Taylor, Esbensen, & Bennett, 1994). From this age onwards, they can also distinguish between someone who acquired knowledge yesterday and someone who is going to acquire it tomorrow – such that only the former has access to the knowledge now (e.g., Busby Grant & Suddendorf, 2010). When one knows that one does not know, one can plot paths towards finding out what is required in the future. A first study of such deliberate information seeking found that 5-, but not 4-year-olds, appropriately sought information they needed to solve a future problem (Redshaw & Suddendorf, 2015). Such reflection on and pursuit of knowledge may well extend to skills. It stands to reason that, in order to monitor what one knows and can do, and what one still has to learn, one needs some common capacity for metacognition.

Through reflection, children may gain some measure of executive control about what future-directed actions to pursue. Such control is critical to allowing thought about the future to drive current action, such as initiating and sustaining deliberate practice over a prolonged period of time and in the face of competing drives. The term executive function usually refers to a range of processes that help to monitor and regulate thought and behavior and guide goal-directed behavior (Beck, Schaefer, Pang, & Carlson, 2011; Carlson, Davis, & Leach, 2005; Carlson, Zelazo, & Faja, 2013; Suddendorf & Corballis, 2007). Even toddlers can demonstrate basic forms of inhibition, such as withholding an automatic response (e.g., Kochanska, Tjebkes, & Forman, 1998). However, young children often have difficulties disengaging from previously rewarding actions and so commit perseveration errors (e.g., Suddendorf, 2003). They gradually acquire capacities to coordinate inhibition and activation prudently. Four-year-olds, for instance, have some capacity – though it often deteriorates over trials - to follow a rule that runs against a pre-potent tendency, as in a Stroop task (Gerstadt, Hong, & Diamond, 1994) or in card sorting first by shape and then by color (Zelazo, Muller, & Frye, 2003). However, they continue to struggle with simple inhibition tasks, such as Simon Says (Carlson, 2005) and with tasks in which they have to self-direct control, such as when asked to sort cards in a new way (e.g., Jacques & Zelazo, 2001). Significant developments in this domain continue to be observed well into adolescence (Luna, Garver, Urban, Lazar, & Sweeney, 2004). One can distinguish three major transitions in the development of control: from perseveration to externally triggered responding; from re-active control to pro-active control; and from environmental triggers to autocuing (Munakata, Snyder, & Chatham, 2012). To self-initiate deliberate practice, the final transition needs to be taken.

The fact that executive control continues to develop into late childhood and beyond, means that children may often struggle implementing actions aimed at imagined future goals, such as sustained practice in the absence of more immediate reinforcers. To diligently pursue deliberate practice, one must resist the temptation to follow more pleasant and more immediately rewarding courses of action. In wait-based delay of gratification tasks, for instance, children have to wait until an experimenter returns with a larger reward. Preschoolers gradually improve in the length of time they are willing and able to wait, with most 4-year-olds only able to resist temptation for a smaller immediate reward for about five minutes (e.g., Atance & Jackson, 2009; Mischel & Ebbesen, 1970). Better control in the preschool years is associated with various advantages later in life (e.g., Ayduk et al., 2000; Casey et al., 2012; Mischel, Shoda, & Peake, 1988; Schlam, Wilson, Shoda, Mischel, & Ayduk, 2013).

In addition to a basic capacity to imagine future events, one must be able to organise current and future actions with longer-term goals in mind, in order to engage in consistent deliberate practice that can shape future skill levels. Similar to children's performance on the wait-based delay of gratification task, children's propensity to make prudent choices to receive a larger reward for later over a small reward for now, increases over the pre-school years (e.g., Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Imuta, Hayne, & Scarf, 2014; Lemmon & Moore, 2007; Moore & Lemmon, 2001; Prencipe & Zelazo, 2005). Through the development in ability to connect the behaviors of the present self with potential outcomes that would be experienced by the future self (recall the Hazlitt quote from above), children gain the self-control to forgo immediate gratification and make future-oriented decisions, such as engaging in deliberate practice.

Another critical capacity for autocuing deliberate practice is the formation of future-directed intentions to practice – and to remember such intentions. The latter is known as prospective memory and research on its development point to significant changes over the later preschool years and beyond (Kliegel, Mackinlay, & Jäger, 2008; Kvavilashvili, Kyle, & Messer, 2012). Note though, that in virtually all prospective memory paradigms, the experimenter instructs the participants as to what they are expected to do (but see Lyons, Henry, Rendell, Corballis, & Suddendorf, 2014 for a new approach), and so we know next to nothing about when children begin to form such future-directed intentions themselves – which would be essential for self-initiating deliberate practice.

No doubt, most children are introduced to deliberate practice by adults, such as parents and teachers, who initially take advantage of incidental practice in play to facilitate skill development (Bloom, 1985). Many parents opt for specific skills being trained in a more dedicated fashion, enrolling their children in music, craft, or sport classes given by experienced teachers and coaches. Social pressures encourage children to keep practicing their skills outside of formal classes to foster improvement. Many children learn the phrase “practice makes perfect” by heart. Immediate rewards (especially praise) are frequently deployed to reinforce incremental steps along the way. Children may or may not eventually adopt their parents’ goals as their own and pursue subsequent skill development on their own accord.

By the age of 6 or 7, most children in countries with compulsory education begin formal schooling (UNISCO Institute of Statistics, 2014), in which practice is systematically encouraged by teachers in academic, physical, and practical education. For instance, children are encouraged to engage in verbal rehearsal in order to memorize information (Bebko & McKinnon, 1990; Bebko, McMorris, Metcalfe, Ricciuti, & Goldstein, 2014; Flavell, Beach, & Chinsky, 1966). This strategy is largely dependent on language proficiency (Bebko et al., 2014) and children with poorer language skills (e.g., deaf children) may not begin to rehearse information until years later (Bebko & McKinnon, 1990). In school, children learn the role that effort plays in achieving success (Gipps & Tunstall, 1998) and are taught strategies to help them regulate their own learning (e.g., Coffman, Ornstein, McCall, & Curran, 2008), but the many effects formal teaching has on children's development go beyond the scope of this essay. Suffice to say that deliberate practice is an essential part of any schooling.

A First Study on the Development of Deliberate Practice

The review of the development of related capacities suggests that the essential building blocks for deliberate practice are only in place around the time formal schooling tends to start. This is probably no coincidence. Yet, there is a lack of formal research on the development of this critical capacity. We know of only one study that has directly aimed at examining this (Davis, Cullen, & Suddendorf, 2015). The researchers conducted two experiments on deliberate practice. In the first, the researchers adopted a version of the above-mentioned rooms-task (Suddendorf et al., 2011) to test 3-, 4-, and 5-year-olds' ability to selectively practice motor task games in one room in preparation of doing such a task in the other room later. In the first room, children were shown four slightly different versions of a motor game (e.g., they had to guide a loop around a wire without touching it), and were given a turn at each version to demonstrate that these were difficult tasks. One version of the game was singled out as a game they would play later to win a sticker reward. Children were then taken to the second room where they could select one version of the game to play with (i.e., to practice on). They then returned to the first room and were given the opportunity to win stickers by playing the game that was singled out. Four- and 5-year-olds, but not 3-year-olds, selected to play the most relevant game in the second room in apparent preparation for a return to the first. It remained unclear, however, whether children made their selection because they wanted to practice for the future, or because this game was singled out earlier without them understanding the relationship between repetition and improved skills.

Experiment 2 therefore examined children's explicit understanding of deliberate practice, while also including one version of the paradigm pioneered in the first experiment. To assess their understanding, children were given a story-based task in which they had to rate which of two puppets was more likely to win a particular competition: one who tried the relevant behavior just once, or one who tried the behavior in question every day for a long period. Following two versions of this task, children were also asked directly what they should do if they wanted to get better at something. Whereas 4-year-olds did not perform above chance on the story tasks, 5-year-olds selected the character who had practiced as the one likely to win a competition over a character who had only done the critical actions once. Furthermore, of the children who selected the correct puppet across both age groups, 83% reported that practice or repetition was the reason why the character would win the competition. When asked directly what they should do to get better at something, two thirds of 5-year-olds mentioned "practice" or "repetition", whereas merely 10% of 4-year-olds did so.

Perhaps most importantly, the performances on the tasks were associated. Those children who referred to practice and repetition were also more likely to pick the practicing character in the story tasks as well as to pick the relevant motor game in their own practice task. This suggests that, by 5 years of age, many children have an explicit understanding of the link between deliberate practice and skill acquisition. They are able to select to practice a task relevant to a future situation, to predict skill change in others based on practice behaviors, and to recognize an association between practice or repetition of behavior and skill improvement. This study provides the first direct indication of when understanding of deliberate practice may emerge in young children, and the results are in line with the developmental data reviewed above. Nonetheless, given that this is a first study, we caution that it certainly requires replication before firm conclusions can be drawn.

Conclusion

Many basic questions remain to be answered. How does understanding of deliberate practice change over time? For instance, when do children appreciate that although practice is effective in some contexts, it has little use in others. Informal observations suggest that many children generalize the idea that practice makes you better even to domains where practice, in fact, makes no difference at all (such as in the ability to throw dice). How do the developmental changes in the related capacities we discussed above influence children’s early understanding and use of deliberate practice? What are the long-term consequences for children when parents do, or do not, encourage intensive deliberate practice? We envisage that future work can unearth both theoretically and practically significant information about this essential human capacity.

In the literature, the adaptive significance of mental time travel into the future has been largely discussed in terms of our ability to flexibly anticipate and prepare (e.g., Suddendorf, 2006), and in terms of our capacity to shape the future world to our design (Dong, Collier-Baker, & Suddendorf, 2015). Here we hope to have demonstrated that the human capacity to shape one’s own future self through deliberate practice deserves considerably more attention than it has received. Thoughts about our future selves tend to trigger emotions and drive many of our actions. Considerable research has documented that we tend to exaggerate the intensity and duration of future feelings (e.g., Gilbert, 2006). One ultimate reason for such a bias may be that it helps us motivate future-directed actions in the face of more immediate urges (Miloyan & Suddendorf, 2015). Forgoing current pleasures in order to practice a skill that we anticipate will give us more pleasure at a future point in time may be a case in point. After all, with diligent practice, we can learn to do very complex things with apparent ease, as Samuel Johnson observed. Without it, we would have considerably fewer skills, less diversity, and less power to control our own destiny.

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