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Expertise and the evolution of consciousness

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Abstract

This paper argues that expertise can be used as an indicator of consciousness in humans and other animals. The argument is based on the following observations: (1) expertise and skill acquisition require deliberate practice; and (2) the characteristics of deliberate practice such as performance evaluation against a more proficient model, retention of voluntary control over actions, self-monitoring, goal-setting, error-detection and correction, and the construction of hierarchically organized retrieval structures are outside of the currently understood bounds of unconscious processing. Thus, to the extent that evidence of expertise exists in an organism, evidence of conscious experience is also present. Two important implications arise from this conclusion: (1) evidence of expertise can be used as the basis for cross-species comparisons of consciousness; and (2) the evolution of human consciousness can be assessed using fossil evidence of skilled behavior as a measure of consciousness.

Keywords: Consciousness; Evolution; Expertise; Deliberate practice; Focused attention; Skill acquisition

1. Introduction

Studying the evolution of consciousness necessarily involves conjectures about the conscious experience of other species. Since direct assessments of another's conscious experience is impossible, these conjectures must rely on indirect evidence which has typically taken two forms: (1) identifying the presence of a cognitive process in another species (generally inferred from behavior) that when present in humans requires consciousness; or (2) identifying specific brain activity in another species as it engages in a certain behavioral act that corresponds to the brain activity found in humans when they

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engage in that act, and that necessarily entails conscious experience in humans (Roth, 2001). These indirect approaches allow for cross-species comparisons that can begin to shed light on the evolutionary history of consciousness.

Unfortunately, these approaches are inadequate for studying the evolution of consciousness specifically along the hominin branch. With only one remaining hominin species, direct behavioral comparisons among hominin species are impossible. Furthermore, neither the cognitive processes nor the brain activity of our extinct ancestors are fossilized with their bones. This seems to render the evolution of human consciousness a scientifically intractable problem. In what follows I will argue that this conclusion is overly pessimistic. A way of assessing the consciousness of our hominin ancestors is available if we focus on the acquisition of expertise as an indicator of consciousness. However, before proceeding too deeply into the argument it is necessary to lay some groundwork concerning expertise and consciousness.

2. Background

2.1. Defining consciousness

Block (1995, 2001) has drawn an important distinction between what he calls phenomenal consciousness and access consciousness. Phenomenal consciousness refers to the subjective "feeling" of a mental state (e.g. what it is like to experience blue or pain) while access consciousness refers to the fact that a mental representation is available for use in reasoning or (more importantly for current purposes) the rational control of action. A number of researchers have argued that when focused attention is brought to bear on a stimulus, the representation of that stimulus is amplified and made widely available to the cognitive system for further processing (Dehaene, Kerszberg, & Changeux, 1998; Kahneman & Treisman, 1984; Posner, 1994). In this paper the term consciousness will primarily refer to the access nature of consciousness which results when focused attention is brought to bear on a stimulus or event.

While phenomenal consciousness and access consciousness are separable concepts, they are closely connected and typically occur together. Normally, when one focuses attention on a stimulus one is both subjectively aware of the stimulus and the internal representation of the stimulus is accessible for a variety of mental processes. Phenomenal consciousness may occur in the absence of access consciousness, such as when we are aware of background noise or peripheral images, but respond to them (if at all) in only limited, reflexive ways (peripheral awareness or fringe consciousness, see Farthing, 1992; James, 1890/1981). The occurrence of access consciousness without phenomenal consciousness appears to be rare and possibly non-existent in the natural world. While Block (1995) claims that access consciousness without phenomenal consciousness is conceptually possible (e.g. zombies, robots, and hypothetical forms of blindsight) he concedes to knowing of no actual examples (p. 233). Thus, it seems reasonable that the "consciousness" involved in skill acquisition will include phenomenal consciousness, but it is the access character of that consciousness that is the necessary prerequisite to the acquisition of expertise.

2.2. Why focus on skilled behavior?

There are at least three compelling reasons to focus on skill acquisition as a means of studying the evolution of consciousness. The first is that evidence of skilled behavior can be found in non-human animals (to be reviewed later). Thus, cross-species comparisons can be made concerning not only relative skill levels but also regarding the processes of skill acquisition. The potential implications for consciousness can be drawn out from these investigations.

Second, a record of hominin skill is preserved in the form of tools and other artifacts. From these remains reasonable conclusions can be drawn concerning the mental capacities needed for their creation. Furthermore, these conclusions can be well-grounded in great ape and human models that represent highly similar species both structurally and neurophysiologically. Thus, the evolution of human consciousness can be studied using a skill acquisition framework.

Lastly, recent developments in neuroscience point to a close connection between consciousness and motor control in primates and humans. Neuropsychological studies indicate the existence of two independent systems for the visual/perceptual control of movement. One system, utilizing the dorsal occipital-parietal pathway, operates unconsciously and mediates immediate responses to visual stimuli. The other, utilizing the ventral occipital-temporal pathway, operates consciously and directs more considered responses based on perceptual representations (Milner & Dijkerman, 2001). The temporal lobe associative cortex has been subject to dramatic expansion over the course of primate evolution. Furthermore, the prefrontal cortex (which is important for conscious awareness) and the cerebellum (which is important for coordinating motor behaviors) have enlarged substantially over the course of primate evolution, reaching their peak size in humans (Deacon, 1997; Dow, 1942, 1988; Passingham, 1982). More importantly, the pathways connecting these structures have also enlarged dramatically, expanding by a factor of five over the course of hominin evolution (Donald, 2001, p. 196). It now seems clear that the cerebellum plays a crucial role in the conscious control of motor behavior as well as other "higher" cognitive functions. Recent neuroimaging studies have indicated that the cerebellar-prefrontal associative system is involved in language, working memory, implicit and explicit learning, the acquisition of new motor skills, and mental imagery (Desmond & Fiez, 1998; Imamizu et al., 2000; Leiner, Leiner, & Dow, 1995; Schmahmann, 1996; Thatch, 1998). Thus, evolution has fashioned the human brain with specific systems that bring consciousness and motor control into a close relationship.

If a strong case can be made that expertise requires a certain level of consciousness, then a potentially productive avenue for studying the evolution of consciousness is opened. Both cross-species comparisons of skilled behavior as well as assessments of hominin skill based on the fossil record can be exploited to answer questions concerning the evolutionary history of consciousness.

2.3. Previewing the argument

The argument to be presented can be summarized as follows: to acquire expertise one must be able to engage in deliberate practice. Deliberate practice requires consciousness, or put more precisely, it requires the accessible mental representations that arise when focused attention is concentrated on a stimulus or event. This type of consciousness is necessary because it exclusively affords the enhanced discriminative powers and response flexibility necessary in order to voluntarily hone behavioral responses. Furthermore, cross-species observations suggest that the ability to develop expertise using deliberate practice may be a uniquely human trait. While animals acquire skills, they appear to do so using play rather than deliberate practice. This difference may be based in the inability of non-human animals to direct attention inwards and willfully retrieve mental representations from memory (autocue). It may be that the conscious capacity necessary to support skill acquisition through deliberate practice is something that evolved solely along the hominid branch, and evidence of this evolution may be discernable in the fossil record.

The case for using expertise as a basis for assessing consciousness reduces to a rather simple set of propositions: (1) expertise requires deliberate practice; (2) deliberate practice requires consciousness; and (3) evidence of expertise exists in both non-human animals and in the fossil record of hominin evolution, and these sources can be used to study the evolution of consciousness. This paper amounts to a defense of each proposition.

3. Proposition 1: expertise requires deliberate practice

3.1. The acquisition of skilled performance and expertise

Modern empirical work on the development of expertise can be traced back to the pioneering studies of de Groot (1946) who found that chess experts were far superior to less accomplished players in their ability to select the best moves after a brief examination of the chessboard. In succeeding decades, a host of studies have examined expertise in a wide range of domains such as: chess (Charness, 1989; Chase & Simon, 1973), medical diagnosis (Elstein, Shulman, & Sprafka, 1990), computer programming (Adelson & Soloway, 1985; Jeffries et al., 1981), music (Ericsson, Krampe, & Tesch-Romer, 1993; Sloboda, 1991), cricket (Lamb & Burwitz, 1988; McLeod & Jenkins, 1991), table tennis (Bootsma & Van Wieringen, 1990), snooker (Abernethy, Neal, & Koning, 1994), volleyball (Allard & Starkes, 1980), and an array of other sports, professions, and activities (see reviews in Abernethy, 1987; Ericsson, 2002; Ericsson & Lehmann, 1996). From this body of data a number of general principles concerning the acquisition of skilled performance have been gleaned.

(1) Expertise generally requires about 10 years of dedicated preparation within a specific domain (the 10 year rule: Chase & Simon, 1973). During this 10 year preparatory period, mere exposure or even active participation in an activity is not enough for the development of elite skill. Instead, a specific kind of preparatory activity called *deliberate practice* is required if the highest levels of performance are to be attained. This leads to the second important principle concerning expertise.

(2) The level of skill one attains in a domain has been shown to be directly related to the amount of deliberate practice one engages in (see Ericsson, 2002 for review and discussion). For example, Krampe and Ericsson (1996) found that the very best

musicians had, by age 20, logged more than 10,000 hours of deliberate practice.

(3) Most elite performers are introduced to their future field of expertise as children in the form of play. While still in this stage, a teacher or coach is typically assigned to harness some of the child's playfulness by setting goals and providing a more structured interaction with the activity aimed at enhancing skill development. Eventually as the child matures and shows greater promise, a full-time commitment to the activity on the part of parents and the child takes place and the highest levels of performance are pursued in earnest (Bloom, 1985). It is during the phase of a full-time commitment that the quality and quantity of deliberate practice become critical in determining how far an individual will take his or her skill. Given the central role of deliberate practice in skill acquisition a closer look at its essentials is necessary.

3.2. Deliberate practice

Deliberate practice is a unique form of activity, distinguishable from both work and play, where goal-directed, concentrated effort is expended in order to hone and improve specific mental and physical skills. An example will help to elucidate its important characteristics: in their analysis of chess expertise, Charness, Krampe, and Mayr (1996) found that becoming a chess grand master involved more than just frequent chess-playing. In their formative years, future chess grand masters improved their skills by spending countless hours studying the games of past grand masters. While studying a game, they would predict the grand master's moves in various situations. When their predictions differed from that of the master, they would go back and re-analyze the chessboard in order to uncover what the master had seen that had eluded them. In this way, they trained themselves to "see" and "think" as a grand master player.

This example highlights one of the central features of deliberate practice, which is *the constant evaluation of one's current skill state against that of a more skilled model*. Specific discrepancies between the model and one's current state are often identified and used as goal conditions for assessing progress. Constant self-monitoring and self-evaluation are necessary (often with the aid of a teacher or coach) in order to assess progress toward achieving goals. In the early stages of skill acquisition one typically focuses on emulating the model and on the process of properly executing the mental and physical strategies necessary for competent performance. In later stages, focus shifts from process monitoring to outcome monitoring, in other words, as mental and physical skills become more efficient and automatic, one concentrates on producing desired results (Schunk & Zimmerman, 1997; Zimmerman, 2002). Thus, a tennis novice may closely watch a model's backhand movements, then concentrate on executing the movement. In time as the movement becomes more natural, the novice's concentration shifts to placing the ball in desired locations.

A second important characteristic of deliberate practice is the *constant focus on the elevation, not maintenance, of skill*. Elevating skill often involves repetitious exercises, however, as Ericsson (2002, p. 29) stresses, deliberate practice is the very opposite of mindless repetition. Once a skill has been acquired and an adequate level of competence achieved, there is a natural tendency for it to become automated (Anderson, 1982, 1987; Fitts & Posner, 1967). At this point, repetitious, less rigorous practice is usually enough to maintain one's skill. This is why simply engaging in an activity, even regularly and vigorously, will not necessarily lead to an individual becoming an elite performer. There are many, many people who play basketball, golf, chess, or their favorite musical instrument on a regular basis, but only a very few elite performers. When engaging in a desired activity, the average person is usually just running off already established, highly automated responses. Deliberate practice, however, requires that the individual resists total skill automation, and constantly challenges himself or herself with new goals and more effective behaviors. Expert pianists, for example, will often purposely rehearse an already learned piece at an excruciatingly slow tempo in order to force themselves to concentrate on the individual notes and the relationships among the notes.

This leads to a third, related feature of deliberate practice: *it requires that a certain level of conscious, voluntary control must be maintained* in order to move beyond one's current ability level to a higher one. Experts need to retain some degree of conscious control over processes in their domain in order to deal with unexpected circumstances or (in the case of sports) the responses of competitors. This "retention of control" has been experimentally demonstrated by Lehmann and Ericsson (1997) who had expert pianists memorize a short musical piece. Afterward, they were unexpectedly required to play the piece again at the same tempo; however, they were required to skip every other measure, or to play with only one hand, or even to transpose the piece into another key. Despite these unexpected changes the accuracy of their performance remained uniformly high. Since the changes required subjects to engage in novel motor movements, Lehmann and Ericsson argued that their pianists were not simply running off an automated motor routine but were using flexibly stored knowledge in an innovative way to meet task demands.

Along with the characteristics just discussed (performance evaluation against a more proficient model, constant elevation of skill, and retention of voluntary control), Ericsson (1996) has identified some other important characteristics of deliberate practice: (a) it involves activity which is at a difficulty level appropriate to but challenging of the individual's current skills; (b) it provides informative feedback concerning the individual's success in attaining new skill levels; (c) it provides opportunities for repetition of new skills; and (d) for the correction of errors as skills are being learned. On an intuitive level it would seem that these features necessarily entail conscious processing. As will be seen shortly there is a strong empirical basis bolstering this intuition.

Two important summary points emerge concerning deliberate practice and expertise. First, deliberate practice in some form is necessary if skill is to be acquired. What separates elite performers or true experts from average performers or novices is the effort and duration of deliberate practice. The average person usually drops deliberate practice for a less rigorous, more repetitious form of practice once an acceptable level of competence is achieved. Experts continue deliberate practice for a much longer time, possibly indefinitely, in order to advance skill to a superlative level (Ericsson, 2002). While there is currently disagreement over whether deliberate practice is *sufficient* for the development of expertise, its *necessity* is unquestioned (Ericsson & Charness, 1994; Sternberg, Grigorenko, & Ferrari, 2002).

Second, the general outline of what constitutes deliberate practice remains the same regardless of the skill to be mastered; and two features inherent to deliberate practice are focused attention and conscious control. Deliberate practice is by its very nature a controlled process that involves highly focussed, concentrated attention on inputs and behavioral flexibility of outputs. So demanding is this activity that only a few hours of it can be sustained in a day's time before rest is required (Ericsson et al., 1993).

3.3. Deliberate practice and the formation of retrieval structures

It may seem paradoxical that the same process, deliberate practice, can be used to acquire expertise across vastly differing domains from chess to snooker to medical diagnosis. And, in terms of the specific knowledge acquired, experts in different fields certainly vary from one another. However, it appears that the generality of deliberate practice lies in the fact that expert performance, regardless of its specific details, involves a common perceptual/motor process – that is, responding effectively to identified meaningful patterns. Deliberate practice trains an individual how to identify and effectively respond to meaningful patterns.

The chess expert, for example, "sees" the chessboard differently, more meaningfully, than does the novice, and is therefore more proficient at selecting the right moves. Chase and Simon (1973) found that chess experts were far more capable at recalling briefly seen chessboards compared to novices. However, the differences were all but eliminated when chess pieces were randomly arranged as opposed to reflecting arrangements from actual games. This shows that the chess experts did not have better memories per se, but instead were able to recognize larger, more meaningful patterns in the game-arranged boards, while the novices were often reduced to trying to remember positions on a piece by piece basis. Similar effects have been found across a wide array of other domains (see Ericsson et al., 1993 for a review).

In the course of developing expertise, one's domain-relevant perceptual experience is altered and enriched. Sensory inputs, which before were chaotic, irrelevant, and unusable, over time emerge as organized, meaningful patterns (Hirst, 1995). This emergent organizing of incoming sensory data is typically accomplished through the construction of *retrieval structures*. Retrieval structures are hierarchically clustered sets of cues that organize incoming data and provide access to domain-relevant information in memory (Ericsson & Kintsch, 1995). An experiment by Chase and Ericsson (Chase & Ericsson, 1981; Ericsson, Chase, & Fallon, 1980) provides a good example of the construction and use of a retrieval structure. These experimenters studied the development of expertise in the digit span memory task by giving a subject, SF, over 200 hours of practice on the task. In the end, SF was able to recall digit strings of up to 80 items. SF did this by organizing the digits into meaningful clusters of groups and supergroups based on mnemonics often involving running times. For example, the four digits 4023 might be organized into a group based on the idea that 4 minutes and 23 seconds is good mile time. This group might then be organized into a larger group based on descending distances (mile, 440, 100 meters). SF would then only have to hold these "larger" structures in working memory and use them as cues to accessing the actual digits. Chess experts have been found to use similar hierarchically organized structures as they assess move sequences while evaluating chess positions and planning moves (Charness, 1981).

A critical expert/novice difference lies in the fact that the expert, as a result of using retrieval structures in working memory, has an organized set of cues that provides access to a vast wealth of domain-specific information stored in his/her long-term memory (Ericsson & Kintsch, 1995). The novice, lacking the retrieval structure, is restricted to that information which can be called into and held in a very limited working memory space at any particular moment in time. Thus, through deliberate practice the expert assembles retrieval structures which organize sensory inputs into meaningful patterns, which in turn provide access to the vast knowledge stored in the expert's long-term memory, which is then used to direct an effective behavioral response.

3.4. Deliberate practice and consciousness

To this point I have argued that deliberate practice produces expertise by training an individual to extract meaningful patterns, which can in turn be used to guide and control efficacious responses. Identifying meaningful patterns entails perceptual discrimination while effectively controlling behavior entails response flexibility, both essential elements of expertise and (as shall be seen) aspects inherent to consciousness as well. This would appear to indicate a close connection between consciousness and the development of expertise using deliberate practice. However, extracting meaningful perceptual patterns and executing adaptive responses may very well be within the capabilities of the unconscious mind. Recent experimental findings show that such processes as visual pattern recognition, rule abstraction, scene categorization, covariance identification, motion detection, fear conditioning, and extracting word meanings can all (apparently) be executed without conscious awareness (Altmann, Dienes, & Goode, 1995; Dehaene, Naccache et al., 1998; Frensch, 1998; Julesz, 1995; Li, VanRullen, Koch, & Perona, 2002; Morris & Dolan, 2001; Ohman & Soares, 1998; Reber, 1993; Watanabe, Nanez, & Sasaki, 2001).

With the unconscious mind seemingly capable of such a potent array of processes, consciousness may be contributing very little in the development of expertise. However, despite the apparent vast powers of the unconscious mind, it is doubtful that one can become an expert unconsciously. The emergent, meaningful patterns used by experts are often *temporally and spatially extended* and therefore beyond the discriminative powers of unconscious processing.

4. Proposition 2: deliberate practice requires consciousness

4.1. Limits of the unconscious mind

Some of the first studies to elucidate the capacity of unconscious processing were those showing residual visual function in patients with damage to the primary visual cortex. These "blindsight" patients had no conscious visual experience, yet they could identify and locate visual stimuli within their phenomenally "blind" fields (Poppel, Held, & Frost, 1973; Weiskrantz, 1986). However, the unconscious processing of blindsight patients can only go so far. While patients can often identify the presence of movement within their blind field they have considerable difficulty identifying the direction of movement (Cowey & Azzopardi, 2001). Similarly, patients with cortical achromatopsia have no conscious experience of color resulting from damage to the visual cortex and possibly the ventral visual pathway (Heywood, Kentridge, & Cowey, 2001). These patients can often succeed on tests of color constancy when only local patches must be compared, but falter when more global judgements across the entire visual scene must be made (D'Zmura, Knoblauch, Henaff, & Michel, 1998; Hurlbert, Bramwell, Heywood, & Cowey, 1998). Note how these "failures" of unconscious processing involve more demanding pattern discriminations across time and space. These findings support the contention made by some (e.g. Searle, 1992) that consciousness provides increased discriminative and computational power compared to unconscious processing.

In addition to neuropsychological studies, the past few decades have seen an impressive accumulation of cognitive research addressing unconscious processing. In reviewing this literature, Dehaene and Naccache (2001) identify three cognitive processes that fall outside the capabilities of unconscious processing and therefore require conscious awareness: (1) durable and explicit information maintenance; (2) novel combinations of operations; and (3) intentional behaviors. As shall be seen shortly, each of these processes involves complex, spatially and temporally extended perceptual discriminations on the input end, as well as response flexibility on the output end.

4.2. Durable and explicit information maintenance

Durable and explicit information maintenance actually refers to two different but related qualities. First, durability (of lack thereof) refers to the fact that implicit and unconscious effects are typically short-lived. Studies of unconscious priming offer a good example of the short-lived nature of unconscious effects. Numerous experiments have demonstrated that the reaction time for determining if a visual stimulus is a word or a non-word letter combination (nurse vs. ydxug, for example) can be affected by a previously presented stimulus. For instance, a subject will render the response "word" to the stimulus "nurse" significantly faster if the stimulus presented just before nurse was semantically related, such as "doctor", as opposed to being semantically unrelated such as "lumber" (Meyer & Schvaneveldt, 1976). Importantly, these same priming effects can be found even when the first word of the pair (doctor in this instance) is masked such that the subject is not consciously aware of its presence (Marcel, 1983). Studies of this type, though, have generally used very brief delays between word pairs, generally ranging from 50 to 150 ms. Unconscious priming effects dissipate very quickly when delays longer than 150 ms are employed, in other words, consciousness is required for more temporally extended effects (Greenwald, 1996).

Explicitness (or lack thereof) refers to the fact that unconscious events or percepts are spatially and temporally unbounded. Treisman and Gelade (1980) demonstrated how certain features of visual scenes such as color, orientation, or shape could exist in a free-floating state in the initial, pre-attentive stages of processing. It is not until attention is focused on aspects of the visual scene that features become unified and "bound" to specific locations in space, leading to the episodic experience of a particular object with certain qualities in a certain location. Prior to this, sensory experience is illusory and its source, as being either externally or internally generated, easily confusable (Kanwisher, 1987; Treisman & Schmidt, 1982).

An experiment by Jacoby, Woloshyn, and Kelly (1989) nicely demonstrates the source confusion produced by the non-explicit nature of unconscious sensory inputs. Two groups of subjects read a list of names of non-famous people. One group gave the list their full attention. The second group, however, read the list in conjunction with a secondary task that prevented them from focusing full attention on the list. In the test phase, both groups were presented with a list that contained: (a) non-famous names from the first list (old non-famous names); (b) non-famous names not from the first list (new non-famous names); and (c) names of famous people. The task for the subjects was to decide if each name was of a famous or non-famous person. The results showed that subjects in the divided attention condition were significantly more likely to call an old non-famous name "famous" than subjects in the full attention condition. This is exactly what would be expected if subjects in the divided attention condition suffered from a source confusion regarding the names on the first list. Why so? Both old non-famous names and famous names should produce a sense of familiarity in subjects. However, if an old non-famous name can be "placed" in its proper episodic context (i.e. as having been seen on the previous list) then even though it is familiar it can be rejected as famous (since all the names on the previous list were non-famous). Subjects who were prevented from giving the first list their full attention had a much more difficult time firmly placing old non-famous names in their proper context and thus made more errors.

The durability and explicitness lacking in unconscious experience indicates that if a representation is to be held in memory for any extended period of time such that its featural properties can be processed and its experience can be contextually bound, then consciousness is typically required.

4.3. Novel combinations of operations

Unconscious processes are generally rigid in their operational constraints and cannot accommodate novel or innovative combinations of operations. A number of studies, for example, have shown the necessity of consciousness in situations where an automated response must be inhibited so that a novel one can be executed. Debner and Jacoby (1994) used a stem completion task where subjects were presented with either heavily (50 ms delay) or lightly (150 ms delay) masked priming words. Immediately after the prime word, the first three letters of the word were presented and subjects were instructed to complete the word with the first word that came to mind *other than* the prime word (called an exclusion task). Thus, suppose the word "button" was the prime word which was shown with a mask occurring either 50 or 150 ms immediately after its onset. Next the subject would be shown the letters "but…" and asked to complete the word. Given typical priming effects one would expect subjects to respond with "button" at levels well above chance. However, to follow the instructions the subject should complete the word as "butler" or "butter" or even "butane", but not "button". The results showed that the two masking conditions had opposite effects on the subject's ability to follow the instructions. When words were lightly masked (150 ms delay) compliance was significantly better relative to a baseline comparison. When words were heavily masked (50 ms delay) compliance was significantly worse relative to a baseline comparison. Thus, some degree of conscious awareness of the word was necessary in order to inhibit or “override” the priming effect of the word and execute a novel response.

In a similar vein, the classic Stroop effect can be reversed but only under conditions where a prime is presented consciously. Merikle, Joordens, and Stoltz (1995) had subjects classify red and green colored patches. Prior to the presentation of the patch, the word red or green was presented either consciously or unconsciously. In either case, when the prime matched the subsequent color (e.g. word “red” followed by a red patch) the classic Stroop effect was obtained – subjects’ ability to name the color was enhanced. However, at one point the experimenters dropped the probability of a match between the prime word and the subsequent color to 25%. This meant that most of the time the prime word “red” actually predicted the occurrence of a green patch and vice-versa. When primes were presented consciously subjects adjusted their behavior and actually became faster when primes did not match colors (effectively reversing the Stroop effect). This reversal, however, did not occur when primes were presented unconsciously. Studies by Cheesman and Merikle (1986) confirmed that only when primes were presented consciously could subjects deploy various response strategies based on the probability of a prime matching or not matching a subsequent stimulus. Strategic behaviors that override automatic ones were not possible when primes were present unconsciously (see also Smith & Merikle, 1999 discussed in Merikle, Smilek, & Eastwood, 2001, p. 127–128).

The ability to inhibit an automatic response and substitute it with a strategically more adaptive one has two important implications. First, it demonstrates a degree of behavioral flexibility that may represent the first step toward autocuing (the capacity to willfully retrieve information from memory rather than having information automatically cued by the environment). Recent studies have shown how difficult it is for apes and monkeys to inhibit automatic responses and substitute them with novel ones (even in situations where information is presented consciously). Boysen and Berntson (1995) used a reverse-contingency paradigm where chimpanzees were allowed to choose between two food rewards of different quantities. Picking the smaller quantity meant that the ape received the larger and vice-versa. Even symbol and language trained apes failed to pick the smaller quantity. Under some circumstances apes and some monkeys can pass the reverse-contingency test and children over 4 years also reliably succeed (Boysen, Mukobi, & Berntson, 1999; Kralik, Hauser, & Zimlicki, 2002; Silberberg & Fujita, 1996). Other studies involving reaching behavior, however, continue to show how difficult it is for non-human primates to inhibit automatic responses (Diamond, 1988; Santos, Ericson, & Hauser, 1999). Paradigms that measure response inhibition abilities across species may provide a window into the evolutionary basis of autocuing.

The second important implication involves the formation of retrieval structures. We saw earlier that with practice, experts organize their domain-specific experience using hierarchically structured long-term memory cues (retrieval structures). In doing so they typically make novel associations among stimuli (such as grouping digits into running times by distances) and strategically organize these associated elements so that they provide reliable access to long-term memory. Given the studies just reviewed, it seems that the formation of retrieval structures necessitates at least some degree of conscious processing.

4.4. Intentional behaviors

Ever since the early descriptions of preserved visual processing in blindsight patients, people have been startled and impressed by the extent and sophistication of unconscious processing (Poppel et al., 1973; Weiskrantz, Warrington, Sander, & Marshall, 1974). However, as Weiskrantz (1997) himself has pointed out, the unconscious abilities of blindsight patients often obscure an obvious deficit. Although they can identify, locate, and direct actions toward stimuli in their "blind" field, blindsight patients never *initiate* these actions, but are pressed into them by persistent experimenters. Their reluctance often stems from the fact that to them it is all quite futile, since they "perceive" nothing and believe themselves to be just randomly guessing. This same inability to initiate action based on preserved implicit processing seems to be shared by all brain damaged patients (Dehaene & Naccache, 2001; Driver & Vuilleumier, 2001; Rossetti, Rode, & Boisson, 2001). The studies discussed earlier showing that subjects are unable to inhibit an automatic response based on implicit input suggest that conscious processing is critical to the intentional acts of normal, healthy subjects as well.

A potential reason why unconscious inputs may be incapable of mediating intentional acts is that they lack the necessary constraints for selecting among a range of potential responses. A classic experiment in conscious vs. unconscious priming by Marcel (1980) demonstrates what this means. In this experiment words with multiple possible meanings were used as primes in situations where they were either masked or unmasked. The context in which a prime word was presented determined which meaning was intended. For example, the prime word "palm" might be presented along with "hand" in which case it would be expected to facilitate the processing of "wrist", but not "tree". However, this effect was found only when the prime was unmasked, and therefore available to consciousness. When the prime word was masked, both contextually relevant meanings (e.g. "wrist") and irrelevant meanings (e.g. "tree") were primed. Marcel (1980) concluded that one of the important functions of consciousness is selectivity. Unconsciously processed words activate all possible meanings, but consciously processed words are constrained in meaning by context. Consciousness then, is necessary in order to understand what a word is about, given its context. We cannot select an effective response to the word until its meaning is appropriately constrained. Intentional responses to objects and events may be similarly designed such that these acts are withheld until we understand what the object is about and how to best react to it – something that apparently requires conscious awareness.

4.5. Deliberate practice and the limitations of unconscious processing

The argument made thus far has two parts: (1) expertise requires deliberate practice; and (2) deliberate practice requires consciousness. Part 1 is non-controversial. As pointed out earlier there is no disagreement in the literature about the relevance or necessity of deliberate practice in the acquisition of expertise. Part 2 is more controversial. However, the discussion just completed on the limitations of unconscious processing should begin to build the case for the necessity of consciousness in deliberate practice. Consider the following characteristics of deliberate practice in light of the limitations of unconscious processing:

(1) *Durable and explicit representations*. Deliberate practice requires that a model's actions be observed and held in mind as one attempts to reproduce those actions. Furthermore, the representation of the model as well as one's self-representation must be capable of providing information about discrepancies between the two so that errors can be detected and corrected. All of this strongly suggests mental representations that are relatively durable and explicit, adequate for guiding the actions of the learner. Learning a tennis backhand, for example, involves a sequence of coordinated movements extended over time and space. The learner's backhand "image" would have to be held long enough in the mind, and be bound precisely enough in time and space, in order to allow the learner to evaluate his/her movements against the image, otherwise it would be useless as a pedagogical tool. The lack of durability and explicitness characteristic of unconscious representations would not be capable of supporting these processes.

(2) *Novel combinations of operations*. Deliberate practice involves the constant transitioning from one skill state to a higher, more proficient one. For this to occur, novel behavioral and mental skills must be acquired and integrated into one's base repertoire. In their analysis of SF's acquisition of memory skill, Ericsson et al. (1980) noted how his progress depended on his ability to devise increasingly sophisticated strategies for organizing information. At first he simply associated digits into groups of four, then into supergroups of three or four, and finally into a three-level hierarchy capable of holding up to 80 digits. For SF to acquire greater memory skill he had to continually find new ways of organizing information. This reflects the fact that experts must continually alter and adjust their behavioral and mental strategies in order to reach more proficient levels of performance. The creation of retrieval structures and the continual acquisition of more effective mental and behavioral responses require consciously combined novel operations and representations.

(3) *Intentional behaviors*. As discussed earlier, conscious awareness appears to be a requirement if one is to inhibit an automated response so that a novel one can be executed. While under many circumstances it can be advantageous to automate responses, automaticity has a price that can be detrimental to the development of expertise. Sometimes signals can be misleading. Bluffs or fakes are common in many sports, such as when a tennis player "disguises" a shot or a volleyball player fakes a spike. In the medical arena, an experienced diagnostician knows that a particular symptom can be highly meaningful in conjunction with other indications, but may be irrelevant or even misleading in a different context. Thus, an expert must be ever able to inhibit initial, automatic responses to sensory data in order to retain the flexibility necessary to react effectively to changing circumstances. This is why one of the important requirements of deliberate practice is that one not allow processes to become entirely automatic. Deliberate practice is not mindless repetition. Experts always retain a certain degree of conscious, intentional control over the actions in their domain. These intentional acts though, appear to be beyond the capacity of the unconscious mind.

4.6. Expertise and implicit learning

The limitations of the unconscious mind just described would appear to preclude it from being capable of supporting the acquisition of expertise. If so, expertise, as developed through deliberate practice, would stand as a definitive indicator of consciousness in an organism. However, a very compelling argument against this could be mounted based on the extensive literature on implicit learning. Decades of research have demonstrated how individuals can acquire novel, sophisticated, abstract rules and associations all without being consciously aware of what has been learned (see Stadler & Frensch, 1998 for a review). This, however, does not necessarily represent a formidable challenge to the notion that consciousness is required for expertise. What the literature on implicit learning demonstrates is that humans, as with nearly all other creatures, possess a powerful unconscious associative learning mechanism (Eichenbaum & Bodkin, 2000; Macphail, 1998). In humans, as with many animals having complex nervous systems, this unconscious associative learning mechanism is linked to and operates in tandem with consciousness.

The classic demonstration of implicit learning comes from Reber's studies on artificial grammar learning (Reber, 1967, 1976, 1989, 1993). Subjects were required to memorize letter strings that were constructed according to a simple set of rules (an artificial grammar). Some of the rules, for instance, stipulated that all strings must begin with either a P or T, that a P could not immediately follow another P, and that a PS combination could only occur at the end of a string. After their initial exposure to letter strings, subjects were told that the strings were constructed according to a "grammar" and that they were now going to see more strings that they would have to classify as either grammatically correct or incorrect. The interesting finding was that while subjects could not verbalize any of the rules of the grammar, they could with remarkable accuracy correctly classify new letter strings as being either grammatical or not. In other words, they learned the rules without being aware that they were learning them, and without being aware of their content. Similar findings have been demonstrated in the learning of variables that control complex systems (see Berry & Broadbent, 1984 for details) and in sequence learning or the serial reaction time task (SRT) where subjects learn to predict where visual stimuli will occur without understanding the rules that determine locations (Nissen & Bullemer, 1987; Reed & Johnson, 1994).

Other recent demonstrations of implicit learning are also worthy of note. Watanabe et al. (2001) demonstrated that coherent object motion could be detected even when subjects were unaware of its presence. Subjects were given a letter identification task against a background of randomly moving dots. Five percent of the dots, however, were moving in a consistent direction. Previous testing had confirmed that this proportion of coherently moving dots was too small to be consciously detected (in other words the dots all appeared to be moving randomly). In tests given a day later or more, subjects were found to have a heightened sensitivity to motion in the same direction as the coherent motion to which they were previously exposed. A similar effect was found by Moore and Egeth (1997) using background dots that unconsciously induced the Muller–Lyer illusion in subjects. Li et al. (2002) showed that subjects could categorize background scenes as containing either an animal or vehicle, even in the absence or near absence of attention to those scenes.

In many respects these studies appear to contradict the limitations on unconscious processing discussed earlier. Subjects demonstrate the ability to acquire complex rules and apply them in novel situations all without an awareness of the process or content of the learning. Using these unconscious rules, subjects can correctly categorize inputs and accurately anticipate their locations in time and space. Furthermore, these effects appear to be durable and long lasting, quite unlike the priming effects discussed earlier.

It is crucial to recognize that studies of implicit learning do not involve the presentation of unconscious or subliminal percepts. What is "unconscious" about implicit learning are the associative processes that go on inside the subject's head. The input on which those associative processes operate is conscious. For example, studies on artificial grammar explicitly require subjects to attend to and often memorize the letter strings embodying the implicitly learned grammar. To my knowledge, no study has ever presented masked letter strings based on an artificial grammar to see if subjects could extract the grammar from subliminal presentation. Likewise, studies involving the control of complex systems and sequence learning all require subjects to attend to the perceptual stimuli on which the learning is based.

While there have been some examples of implicit learning of unattended stimuli in dual-task paradigms (e.g. Berry & Broadbent, 1988; Cohen, Ivry, & Keele, 1990), these have been challenged based on the notion that even a secondary task cannot entirely prevent attentional shifts to the relevant dimensions of the to-be-learned stimuli. After a series of studies in sequence learning, for example, Jimenez and Mendez (1999) concluded that selective attention to the predictive aspects of the stimuli were necessary for learning to take place. Other researchers have drawn similar conclusions. Berry (1991) argued that interaction, and not just observation, was necessary in order to (implicitly) learn how to control a complex system. Similarly, Berry and Cock (1998, p. 141–142) report that the implicit rules guiding a particular task were only learned when subjects were instructed to pay attention to that particular task, and were not learned when subjects' attention was directed elsewhere. A number of studies have demonstrated that implicit learning can be interfered with or eliminated entirely when secondary tasks are included along with the intended learning task (Frensch, Buchner, & Lin, 1994; Nissen & Bullemer, 1987). After a series of studies looking at the question of attention in implicit learning, Reed and Johnson (1998, p. 278–281) concluded that "implicit learning processes are influenced by the availability of cognitive resources and therefore cannot be considered automatic in the strict sense" (p. 281). Recent studies demonstrating the necessity of attention in implicit priming and associative learning have lent further support to this line of reasoning (Naccache, Blandin, & Dehaene, 2002; Pessoa, Kastner, & Ungerleider, 2002).

Thus, consciousness plays an important role in implicit learning. Subjects are consciously aware of the stimuli on which the implicit learning is based. They are not, however, aware of all the properties inherent to those stimuli. For example, in the Watanabe et al. (2001) study subjects were aware of the background dots, and the movement of those dots. They were unaware of the *coherent movement* of a small subset of those dots. Similarly, in the Li et al. (2002) study subjects were aware of the background scenes and the presence or absence of animals in those scenes (personal communication).

In artificial grammar learning subjects are aware of the letter strings, but they are unaware of the rule-based structure of the strings.

4.7. The role of consciousness in implicit learning

Why would consciousness be necessary for implicit learning? Implicit learning typically involves extracting the covariant relationships among stimuli. Extracting these structural relations requires that stimulus features be temporally and spatially "bound" in one's experience. The enhanced discriminative powers of consciousness appear to be essential for this binding to occur. Consider for a moment the implicit learning of an artificial grammar. Extracting the "rules" of the grammar requires that rather sophisticated spatial/temporal discriminations be made. One must recognize that a lawful pattern requires a T or P at the beginning, that a P followed immediately by another P is unlawful, and that the pattern PS is only acceptable when located at the end of a string. Recognizing these properties in the letter strings as they are initially being presented necessarily means that the elements of the strings (the Ps and Ss and features therein) be located spatially and temporally in one's experience and not free-floating, as occurs pre-attentively (Treisman & Gelade, 1980). The spatial/temporal associations required for the implicit construction of the grammar would not even be available for learning (implicit or otherwise) unless first attended to and therefore consciously experienced. Consciousness makes these properties available for associative learning and some of that learning appears to occur unconsciously.

4.8. Anomalous findings

A critical test of the importance of consciousness to implicit learning would be the extent to which truly unconscious learning is possible. In other words, this position predicts that implicit learning based on subliminally presented stimuli (such as the subliminal artificial grammar study suggested earlier) is either impossible or greatly limited. Unconscious associative learning could not, for example, require the association of stimulus properties that extend in any substantive way across time and space (the defining of "substantive" would, of course, be an empirical issue). One demonstration of unconscious learning, though compelling, appears to fit within these predicted constraints.

Unconscious learning has been demonstrated in the area of "prepared" fear conditioning. A number of experiments have presented certain stimuli as CSs (such as snakes, spiders, and angry faces) in masked conditions paired with an aversive UCS and later found a fearful response (such as increased skin conductance) to the CS alone (Esteves & Ohman, 1994; Morris & Dolan, 2001; Ohman & Soares, 1998). These same effects were not found when non-fearful stimuli (flowers, happy faces) were used as masked CSs and paired with a UCS. For example, Morris, Buchel, and Dolan (2001) (discussed in Morris & Dolan, 2001, p. 191) paired a masked angry face (CS +) with an aversive 100 dB noise. This same face and a second angry face (CS −) were also presented consciously but without being paired with noise. Subsequent testing showed that subjects had no conscious awareness of the angry face–noise pairing, however, increased skin conductances were observed to later unmasked presentations of the CS + relative to the CS − face.

Studies such as these suggest that humans do have the capacity for implicit associative learning based on subliminal experiences. There are, however, two important factors to consider about this effect. First, there is evidence that the fear inducing stimuli used in these studies (snakes, spiders, and angry faces) are, by evolutionary design, ones that "pop out" pre-attentively (Fox et al., 2000; Hanson & Hanson, 1988; Ohman, Flykt, & Esteves, 2001). Second, the response measured is a simple physiological change in skin conductance, which could also be the result of evolutionary hard-wiring. It may very well be that unconscious learning is largely restricted to evolutionarily "prepared" stimuli where the associations have high survival and reproductive value and the responses to those stimuli are narrow in scope. For an organism, such as humans, where adaptability often means a range of responses must be available to a variety of stimuli, conscious awareness may be the most effective mechanism for processing inputs and directing responses.

A second anomalous finding comes from the implicit memory literature and is less easily dismissed. Implicit memory occurs when someone shows behavioral evidence of memory, but without any conscious recollection of the relevant event underlying the behavior. For example, suppose a subject is shown a list of words and asked to repeat them aloud. Among the words is "scheme". Later the subject is given a stem completion test with the stem "sch…" as one of the items. It is likely that the subject will fill in the word "scheme" at a higher than expected level even if the subject fails to recall the presence of this word from the original list. The same argument presented with implicit learning is also relevant with implicit memory. That is, the original experience of the later-tested items is conscious. Thus, as was true with implicit learning, consciousness is involved during the encoding process in implicit memory. However, at least one study has shown implicit memory effects with subliminally presented items.

Bonebakker et al. (1996) presented a list of words to patients undergoing surgery with general anesthetic. On a stem completion test given 24 hours later subjects demonstrated implicit memory for the list words presented during surgery. This would suggest that under some circumstances even unconscious events could have long lasting effects in memory. It is unclear how robust or generalizable this sort of subliminal implicit memory effect is. Furthermore, as with nearly all implicit memory findings, the effects appear to be restricted to ones of increased perceptual fluency, that is, enhanced stimulus processing based on previous exposure. While perceptual fluency plays a role in the development of expertise, it is not, by itself, sufficient for expertise.

Finally, the much-discussed work of Benjamin Libet (1985) might also be interpreted as challenging to the arguments being posed here. Libet monitored subjects' brain activity as they engaged in simple motor acts such as flexing the wrist or fingers. He found that a negative shift in electrical potential (a "readiness potential") preceded the subject's conscious desire to engage in the motor act by about 350 ms. Thus, both the motor act itself and the conscious awareness of "willing" the act were subsequent to a preconscious cerebral output. The conscious initiating and controlling of behaviors (as is essential in deliberate practice) may themselves be unconsciously determined by antecedent brain processes.

Libet's work and the interpretation of it are controversial (see the numerous reactions included with his 1985 paper). It remains an open question as to why some acts are accompanied by a sense of voluntary control while others are not, and what functional role this sense might play. Libet himself has proposed that the function of consciousness is not necessarily to initiate acts but to monitor and potentially inhibit certain ones. Other findings, such as Lhermitte's work with brain damaged patients who uncontrollably imitate observed or cued gestures, are consistent with this view (Lhermitte, 1986; Lhermitte, Pillon, & Serdaru, 1986). This syndrome, dubbed "environmental dependency syndrome" by Lhermitte, renders the patient unable to inhibit stored motor routines even when they are socially inappropriate (such as a patient giving a urine sample without first going to the restroom). The exclusion studies reviewed earlier (where subjects are required to complete a word with anything other than a prime word seen earlier) also demonstrated the necessity of consciousness when one must inhibit a stereotypic act and replace it with a novel one. It may be this "censor and replacement" function of consciousness that is essential in the development of expertise.

4.9. Implicit processing: conclusions

The important point to be gleaned from this discussion of implicit learning and memory is that demonstrations of implicit learning and memory do not seriously call into question the role or importance of consciousness. The discriminating power of consciousness is a part of implicit processing and as such is one of the reasons why implicit processes can possess properties such as durability and the capacity to deal with novelty, that are absent when unconscious processes are isolated.

It is entirely plausible that some of the learning acquired by experts during the course of deliberate practice is implicit in nature. A professional tennis player, for example, may not be entirely aware of all the inter-relationships among cues that indicate the velocity, destination, or spin properties of an opponent's shot, but may detect their presence and effectively respond to them, nevertheless. Thus, I contend, the original argument remains intact: expertise requires deliberate practice, and deliberate practice requires consciousness. Accepting the validity of this argument, we can now move on to Proposition 3.

One of the strengths of assessing consciousness from a skill acquisition perspective is that it allows for cross-species and paleoanthropic comparisons. Skills can be evaluated in non-human animals and evidence of skill can be gleaned from the fossil record. The next section shows that a skills framework can be successfully applied to these domains and addresses some of the issues and questions that arise when doing so.

5. Proposition 3: evidence of expertise exists in both non-human animals and in the fossil record of hominin evolution, and these sources can be used to study the evolution of consciousness

5.1. Do animals practice?

If animals attain skills using processes comparable to human deliberate practice, then this could count as evidence for a conscious experience comparable to humans. An important implication of the current approach is that it points directly to animal skill acquisition as fertile ground for cross-species research. Certainly many animals must acquire skills. Cheetahs must acquire hunting skills. Chimps, otters, and other animals acquire tool-use skills. Even some dogs become quite proficient at Frisbee-catching. The critical question, though, is how these skills are acquired. Decades ago, Symons (1978) documented considerable evidence that rhesus monkeys acquired both predator avoidance skills and fighting skills (especially for males) through play. His work suggests that animal skill acquisition is based on practice, but it is "play" practice, not deliberate practice. A challenge for future research will be in teasing apart and testing these different concepts by clearly defining what is meant by practice and when practice qualifies as something comparable to human deliberate practice.

Future observations may exploit the fact that deliberate practice is often a more solitary activity compared to play. Additionally, the range of behaviors exhibited in deliberate practice is typically narrower compared to those associated with play. A youngster learning to dribble a basketball, for example, concentrates on repeating certain motions that allow him/her to control the movement of the ball. By contrast, a kitten playing with a ball seems more intent on creating and then reacting to widely divergent ball movements by swatting it left and right or rabbit-kicking it upwards. Future animal observations will need to focus on solitary animal activities that appear to concentrate on a restricted range of behaviors. In reviewing the literature on animal skill acquisition it can be seen that the notion of "practice" has been used very generally to apply to nearly any process of skill improvement.

Goodall (1976), for example, in describing the behavior of young chimpanzees states, "Often, after watching some activity such as a male charging display or a complex tool-using performance, an infant may then try to perform the same actions. Subsequently he may *practice* the behavior time and time again." (p. 88; italics added). The description ends there so it is difficult to assess just what manner of practice this was. Ripley (1967) describes how juvenile gray langur monkeys (*Presbytis entellus thersites*) improve their jumping ability by jumping from ground to branch several times in a row or leaping over and over across a gap between two tree branches. These actions were all done in the context of play, but the question remains as to whether the animals had some "model" behavior in mind as humans do when perfecting a dive or ballet leap.

Goodall (1990) provides another interesting account of what she termed "practice" in an adolescent male chimpanzee. The chimp, Figan, had observed another chimp, Mike, incorporating empty four-gallon tin cans into his charging display. The noisy cans were hugely successful in intimidating the other males, thus permitting Mike to ascend to alpha status. "But Figan was the only one whom we saw, on two different occasions, 'practising' with cans that had been abandoned by Mike", describes Goodall (p. 44). "Characteristically – for he was a past master at keeping out of trouble – he did this only when out of sight of older males who would have been intolerant of such behaviour in a mere adolescent. He would undoubtedly have become as adroit as Mike had we not removed all cans from circulation." This account suggests that Figan went off by himself with the specific intent of exploring (and perfecting?) how the cans could be used as part of one's charging display. It is also possible, however, that Figan was simply emulating behaviors he had previously observed in Mike, while being well aware of the fact that such behaviors could be dangerous under certain conditions (in the presence of older males).

Griffin (2001) uses the term "practice" to describe the behavior of African village weaver birds (*Ploceus cucullatus*) as they made their first attempts at nest building after watching older males build theirs. These initial nests were often incomplete and improperly constructed, and were therefore rejected by females. After more rounds of observing and building, eventually the bird was able to produce a competent nest. "Thus" says Griffin, "the male that builds the relatively complex structures has ordinarily had a long period of practice and has also had abundant opportunity to watch older males build more complete nests" (p. 91). A similar process occurs with bowerbirds (*Ptilonorhynchus violaceus*; Diamond, 1982).

The process being described in these cases can be understood as one of emulating observed behaviors, followed by environmental feedback (rewards, lack of rewards, rejection or acceptance by potential mates, etc.), followed by more observation and emulation and so on until a product worthy of environmental reward or acceptance has been rendered. Is this a process of skill acquisition based on deliberate practice? Both involve the use of a more skilled model as a comparison. Both involve opportunities for environmental feedback and error correction. Furthermore, as Darwin (1871, Chap. 3) himself noted many animals manifest obvious indicators of externally focused attention and presumably therefore experience a state of sensory awareness similar to humans. But more rigorous tests are needed to truly answer this question.

Another common context for practice is during the course of instruction. Caro and Hauser (1992) reviewed the reports of teaching among animals, concluding that among non-primates the clearest examples of active instruction are found among predatory cats. A mother cheetah, for example, will bring back a captured prey to her cubs and allow them to chase and kill it under her supervision. As the cubs mature and their hunting prowess increases, the mother cheetah adjusts her level of involvement in these supervised hunts, thus matching her "instruction" with their skill level (Caro, 1994). A similar process can be readily observed among domestic cats. In one way, at least, this process resembles the deliberate practice of humans in that the behavioral demands placed on the learner are constantly adjusted to fit his/her developing skill level. However, as any cat owner can testify, the overall context of this activity appears to be one of playful interaction on the part of the nascent predators, rather than the concentrated effort characteristic of a human aspiring toward expertise.

These examples suggest that some elements of deliberate practice may be present in animal skill acquisition. However, more systematic observations and experimental tests are necessary to make more definitive statements on this issue. Experimental situations might be set up where a novel behavior leads to a reward and animals are given the opportunity to improve their skill on this behavior. For example, Whiten, Custance, Gomez, Teixidor, and Bard (1996) created an artificial "fruit" as an experimental analogue to the picking, peeling, and shucking problems that chimpanzees often face while foraging in the wild. The apes were required to perform a series of novel manipulations on the "fruit" before it would yield a reward. An interesting question could be posed with this sort of paradigm. If a set of novel behaviors leads to a desired reward and greater efficacy in those behaviors is linked to greater rewards, then will the chimps deliberately practice at those behaviors in order to improve their skill? A task modeled on the Whiten et al. (1996) approach might effectively address this issue.

5.2. Is deliberate practice uniquely human?

Despite the potential similarities between human and animal skill acquisition at least one researcher has argued for a critical, possibly unbridgeable difference. Donald (1999) argues that only humans can engage in deliberate practice because of what he terms the lack of "autocuing" in animals. Autocuing refers to the capacity to gain voluntary control of the contents of one's own mind – to self-trigger memories (Donald, 1993). Skill development in non-human animals is sorely limited by the fact that the animal requires external cues in order to gain access to the stored motor responses that must be shaped and "trained-up" for greater efficacy. Donald (1999, p. 143) contends:

> You cannot rehearse what you cannot recall. If an animal depends entirely upon environmental triggers to remember when and what to rehearse, skill development becomes extremely difficult, since the animal cannot self-trigger the memories supporting the skill, and effectively hangs in suspended animation until the environment provides the cues needed for retrieval of a given response-pattern. Trainers of apes have had to cope precisely with this limitation; for instance, it often takes thousands of trials to establish a reliable signing response in a chimpanzee (Greenfield & Savage-Rumbaugh, 1990).

An essential element of deliberate practice (and thus of skill acquisition) is the ability to focus awareness inward, away from the environment and onto one's own actions (Donald, 1999). It is not uncommon for a human to spend countless hours bouncing or shooting a ball, skipping rope, or hitting a tennis ball against a wall, all the while adjusting motor actions and experimenting with different combinations of movements to evaluate their efficacy. Though animals may repeat actions, they simply do not spontaneously rehearse and refine their movement patterns. As Donald succinctly puts it: "Baboons throw projectiles in a fight, but they don't systematically practice and improve their throwing skill" (Donald, 1993, p. 152).

Though tantalizing, the examples reviewed earlier have provided no definitive evidence that animals can or do engage in deliberate practice. If Donald is right, then any systematic studies addressing this issue should ultimately come up empty. However, the similarities documented between human and animal practice are intriguing and certainly do not preclude the possibility that animals may practice as humans do (at least to some extent). If so, this would have important implications for their level of consciousness.

5.3. Skill development in hominin evolution

A second important implication of a skills approach to consciousness is that evidence of skill can also be observed in the fossil record of human evolution. The evidence comes in the form of fossil artifacts, mostly tools, left behind by our hominin ancestors. What is interesting about these artifacts is that they do suggest evidence of skill acquisition using deliberate practice.

The earliest stone tools, called the Oldowan industry, appeared about 2.5 million years ago (mya) and consist of small flakes broken from a core stone (Semaw et al., 1997; note: both the flakes and cores may have been used as tools). Though there is no evidence that apes can create Oldowan-type tools in the wild, captive apes have created tools approaching those of the Oldowan industry (Toth, Schick, Savage-Rumbaugh, Sevcik, & Rumbaugh, 1993; Wright, 1972). Most researchers agree that the early hominins who created Oldowan tools may have possessed a degree of motor control and timing that exceeded that of apes, however, this did not represent a major intellectual advance (Toth, 1985; Wynn, 1996, 2002). The same, however, cannot be said for the next major category of tools to emerge, the Acheulean industry.

The earliest Acheulean tools are about 1.5 million years old and are distinguishable from the Oldowan by their larger size and sophistication. An exemplar of the Acheulean industry is the hand axe, which was created by trimming flakes off around the sides of a core, producing a teardrop shaped, roughly symmetrical tool. Unlike Oldowan tools, hand axe construction (especially later hand axes which emerged around 0.6 mya) would have required considerable investment in time and energy, with the toolmaker going through a series of flaking iterations before completing the final product. Wynn (1981, 2002) has argued that the late Acheulean hand axe maker, unlike his Oldowan counterpart, could not simply have focused on the shape of the tool's edge, but instead had to understand how flakes trimmed from one part of the stone affected the tool's overall shape. He contends that to create such a tool, it would be necessary to hold in mind multiple perspectives of the tool as it was being created so that the toolmaker could appreciate how a flake removed from one side would affect the total shape of the tool. Thus, the late Acheulean hand axe may provide us with the first evidence of hominin motor behaviors guided by a durable and explicit mental image – the first step toward skill acquisition via deliberate practice.

At a number of sites where hand axes have been found, hundreds have been unearthed showing no evidence of use (Klein & Edgar, 2002, p. 107; Kohn & Mithen, 1999). Kohn and Mithen (1999) contend that hand axes may have served an important function in mate selection. A male who could produce a high quality hand axe may have been signaling his industriousness, competence, and overall mate quality (good genes) to local females. Do the hundreds of unused hand axes represent evidence of hominins practicing axe-making skill? If so we might expect to find hand axes of varying quality. Toth (1985) demonstrated that the final form of an Oldowan tool depended more on the raw materials the toolmaker started with than the intentions of the toolmaker. If hominins were practicing hand axe making we might expect a similar analysis to reach the opposite conclusion for Acheulean hand axes. Furthermore, if hand axe-making skill was essential in mate selection, then we could expect the ability to acquire hand axe-making skill (i.e. the ability to practice) to be under selection pressure and therefore evolving over time.

Around 250,000 years ago, the Acheulean industry was supplanted by Middle Stone Age (Africa) or Mousterian (Europe) technologies. Of great significance during this period was the advent of composite tools – tools created by combining component elements. "Hafted" tools, for example, were ones composed of three distinct elements or technounits, usually (1) a stone blade, affixed to (2) a wooden handle using (3) an adhesive or some binding material (Oswalt, 1976).

Ambrose (2001) has drawn parallels between the cognitive requirements of composite tool production and the grammatical constraints of language. Both, he argues, require the ability to organize thought and action sequentially and hierarchically. To create a composite tool one must organize a sequence of actions, such as breaking off the stone flake, fashioning the handle, affixing the blade to the handle, etc., and one must understand how these actions and the tool-elements inter-relate to one another. Creating a sentence requires a similar understanding of how the concepts of agent and action relate to one another and how vocal responses must be organized sequentially in order to effectively express these relationships. Similarly, expertise requires the construction of hierarchically ordered retrieval structures, which serve as cues to domain-specific knowledge and organize one's experience of and responses to domain-relevant input. Composite tools provide the first evidence of this hierarchically structured form of thinking and behaving being externalized to create fitness-enhancing implements, thus placing them under selection pressure.

Finally, the fossil record of hominin evolution seems to provide a clear marker as to when self-consciousness emerged. With the Late Stone Age (LSA) in Africa about 50,000 years ago, and the more well-documented Upper Paleolithic (UP) Revolution in Europe about 40,000 years ago, the first unequivocal evidence of a fully human self-awareness is present (Klein & Edgar, 2002; Mellars, 1996). For the first time hominins engaged in the widespread creation of symbolic artifacts, personal adornments, jewelry, and art. These artifacts represent humanity's first attempt at symbolically representing themselves, their world, and their place in it. One of the most dramatic examples of this is the Chauvet cave in southern France where more than 260 drawn, painted, and engraved animals, geometric patterns, and other representations dated to around 30,000 years ago have been uncovered (Chauvet, Deschamps, & Hillaire, 1995). Equally old statuettes, figurines, and other symbolic artifacts have also been unearthed (see Klein & Edgar, 2002, p. 260–263).

The LSA/UP era not only provides our first unequivocal evidence of an emerging hominin sense of self, but also evidence that this self-awareness could be defined in terms of behavioral skills. It now appears that the vast majority of the over 260 Chauvet cave drawings were produced by a single artist (Clottes, 1996). While art was likely shared and valued by the entire tribe, this strongly suggests that its creation was often the domain of specialists. Specialization also appears to have emerged in other areas. UP tools include some that were intended solely for ritualistic or symbolic purposes, such as some Solutrean blades which were so exquisitely thin that they could not have held up as working implements. Instead, their only value seems to have been ceremonial, possibly as a celebration of a particular toolmaker's skill. The UP period also provides our first unequivocal evidence of musical instruments in the form of simple flutes made from bird bones (d'Errico, Villa, Pinto Llona, & Ruiz Idarraga, 1998; Turk, Dirjec, & Kavur, 1995). As with art, tools and music were most likely shared among tribal members, however, the expertise required to create ceremonial blades or to play bone flutes was probably restricted to a skillful few. What all of this suggests is that among UP peoples, social roles based on acquired skills such as artist, tool-maker, hunter, musician, leader, and possibly shaman were emerging and the ability to develop these skills through practice was evolving.

5.4. Final questions

Using skill acquisition as the framework for the evolution of hominin consciousness raises other related issues. For instance, a number of researchers have argued that throwing ability played a critical role in human evolution, especially in the evolution of language (Calvin, 1993; Noble & Davidson, 1996). Studies by Blumenschine (1986, 1987) and Potts and Shipman (Potts & Shipman, 1981; Shipman, 1986) strongly suggest that early hominins filled a scavenger niche in Pliocene Africa. If so, this would have been odd behavior for an ape. Our closest relative, the chimpanzee, rarely scavenges and is a poor thrower (Stanford, 1999; van Lawick-Goodall, 1968; Westergaard, Liv, Haynie, & Suomi, 2000). But humans, especially hunter-gathers, can be superb throwers (Corballis, 2002, p. 79). Bunn and Ezzo (1993) argue that early hominins may have survived as scavengers by chasing off larger predators after they had made a kill. If so, did our ancestors do this by throwing stones at them? And did they become proficient stone throwers by practicing the behavior?

Another interesting question involves the demise of the Neanderthals. It has long been accepted that *Homo sapiens* and not Neanderthals created the vast majority of the symbolic artifacts of the UP. But humans showed other skill differences from Neanderthals as well, including the creation of tailored clothing, built shelters, and the manufacture and use of nets and traps in hunting and fishing (Hoffecker, 2002). Do these skill differences also represent differences in consciousness? Further research is required to understand the connection between consciousness and skills such as these. Establishing those connections may help to unravel the mystery of why humans and not Neanderthals emerged from the UP.

6. Summary

Expertise requires deliberate practice. Deliberate practice requires consciousness. A framework built on these premises can prove useful for examining the evolution of consciousness by allowing for cross-species comparisons and for assessing the consciousness of our hominin ancestors. As this paper has tried to show, approaching consciousness from the standpoint of acquired expertise raises a number of interesting and important issues, many of which appear amenable to empirical tests. To make scientific progress on the complex issue of consciousness a variety of different models may be necessary in attacking the problem. A skills-based model holds promise as an effective addition to current approaches.

7. Uncited References

Ambrose, 1998. de Waal and Luttrel, 1988. Wilkinson, 1984.

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