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# The co-evolution of tools and minds: cognition and material culture in the hominin lineage

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**Abstract** The structuring of our environment to provide cues and reminders for ourselves is common: We leave notes on the fridge, we have a particular place for our keys where we deposit them, making them easy to find. We alter our world to streamline our cognitive tasks. But how did hominins gain this capacity? What pushed our ancestors to structure their physical environment in ways that buffered thinking and began the process of using the world cognitively? I argue that the capacity to engage in these behaviours is a by-product of increased tool investment and tool curation, which in turn was necessary because of increasingly heterogeneous environments. The minute tools are carried and cared for, they begin to undergo selection for added functions, becoming available as cognitive primers and as signals. I explore the trajectory of this co-evolutionary feedback loop of hominins and their tools, and demonstrate the role tools have in shaping our thinking.

**Keywords** Human evolution · Extended mind · Archaeology · Evolution · Hominins · Handaxes

## Introduction

The archaeological record is a crucial source of information about the evolution of human cognition. With appropriate caution, we can use the archaeological record to detect changes in behaviour and changes in the underlying cognitive skills that drive behaviour. But too often, the archaeological evidence is seen somewhat simplistically as the *result* of behaviour, and thence cognition. The cognitive skill comes first, and the archaeologically visible cultural product comes second. This paper turns this traditional

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view of evidence around. This paper argues that we should view archaeological evidence as one half of a feedback loop between the world and the cognition of our evolutionary ancestors. Tools and minds co-evolve, and we will examine the co-evolution of stone tools with the early members of the *Homo* genus from the early Pleistocene[1] of approximately 2.6 million years ago (mya) to approximately 1 mya.

Within archaeology and the study of human evolution, the standard view is that the cognitive capacity comes first and the cultural product comes second. For example, tools showing evidence of standardisation in design represent a capacity to maintain a *mental* template—hominins are making something with some design goal in mind (Wynn 2002; McNabb et al. 2004; Lycett and Cramon-Taubadel 2008; Lycett and Gowlett 2008). The notion here is that minds *enable* behaviour and culture. The causal arrow is one way; from minds to culture, and the research strategy is one of reverse engineering cognition from evidence of behaviours. With this assumption, the archaeology of human cognitive evolution is a science of detecting changes in cognition based on changes in material culture. The invisible cognitive processes of past hominins are only accessible once those cognitive processes impact on the world in ways that leave detectable traces recoverable by the methods of historical sciences (Cleland 2002; Jeffares 2008).

What this means is of course that the archaeology of cognition faces a constant dilemma of a potential lag between a cognitive development and evidence for that development detectable by archaeologists. 'Absence of evidence is not evidence of absence' has been a constant worry for those seeking to understand the timing, trajectory and evolution of human cognitive developments. Cognition enables behaviour, not all behaviours will leave traces in the archaeological record, and so the problem simply would not go away.

Yet, we know, and have known for some time in various ways, that a simple causal arrow from cognition to behaviour is false. There is a collection of approaches to cognition that recognise that cognition is not just something that happens *in here* in our head about the world *out there* around us. Cognition does not just shape behaviours which then shape the world: the world shapes our cognition.

In this vein, Andy Clark has argued that we should abandon the simple Cartesian model and embrace a view of minds as embodied (Clark 1997, 1999) and extended (Clark and Chalmers 1998; Clark 2008). The view that cognitive skills and mental content are inherited hardwired neural structures is implausible on a number of grounds (Cowie 1999). Consequently, this view has also been coupled to ideas about how skills develop as well. Psychologists, philosophers and the cognitive sciences in general are proposing new ways in which cognitive capacities are shaped by the developmental process. Thus, Karola Stotz and others (see Stotz 2010) have stressed the importance of developmental factors in shaping the cognition of individuals.

What's more, this developmental and plastic learning paradigm has an important trans-generational component. Kim Sterelny has worked with the niche construction framework of John Odling-Smee, Kevin Laland and Marcus Feldman (Odling-Smee et al. 1996, 2003; Laland et al. 2000) and built a model of human cognitive evolution that takes seriously the social world of hominins as part of an inherited

[1] Note: Pre 2009, the International Union of the Geological Sciences designated the Pleistocene as starting at 1.8 mya. This paper uses the IUGS' new designation of the Pleistocene, with a start of 2.588 mya.

epistemic and informational environment (Sterelny 2003). The idea that cultural products and behaviours are importantly bound to thinking, and play a role in cognitive systems, is part of a general paradigm that is becoming if not orthodoxy, then a mainstream alternative within the cognitive sciences.

What this means for archaeology, and in particular, the archaeology of pre-*Sapien* hominins, is only beginning to be explored. This paper is part of that exploration. This paper starts with the view that the cultural products and archaeological evidence associated with human evolution need not be seen as the final evidence of a cognitive capacity. It can, in some cases, be the *cause*, the trigger, of a new cognitive capacity. By using the example of the earliest stone tools, we can examine this new causal loop.

## The archaeological project

The traditional view of the relationship between minds and environments forced archaeologists to be behaviourists. Environmental inputs go in, behaviours come out, and some of those behaviours result in material cultural artefacts. There is a long causal chain here, with a black box, the mind, in the middle of it. It is no wonder that we feel a little constrained as to how much we can speculate on the cognitive skills of an artefact's maker. The problem is aggravated in the evolutionary context by the enigmatic function of some tools. However, the post-Cartesian framework outlined above offers us new possibilities. Tools are not only the outputs of behaviours, they play a role in thinking: They are supports and sometimes components of the thinking process. There are feedback loops between elements of the environment and cognitive processes 'in the head.'

This changes our potential research strategies, for on this view we have distinctly more access to cognition than that allowed for by older paradigms. Tools are important components in the thinking process. The situation is then less like a black box, and rather like a clock with some of the mechanisms available for inspection, even while some elements remain hidden. We can gain a much richer insight into the invisible components of the cognitive systems via the visible components. The perishable elements of past cognitive systems can be reconstructed based on observations of the non-perishable impacts of those systems, or by observations of their interaction with non-perishable, and archaeologically visible, elements. Some of the traces of cognitive processes will be the tools themselves, various environmental impacts or traces elsewhere in the remains of the system. For instance, habitual tool use will potentially change bone densities in a hominin's limb (Eckhardt 2000). The interaction of cognitive elements across the system leaves traces of those interactions, and this can form the basis of evidence that allows us to reconstruct the invisible components of cognition.

This insight will not be complete, and requires a deep understanding of how material culture might play a role in the life of hominins. Nevertheless, it changes the prospects for cognitive archaeology.

Moreover, the claim that the cognition comes first, and the cultural product second, is no longer a viable axiom or even heuristic. It is not just possible, it is highly likely that new elements of the environment will shape and structure subsequent cognitive evolution. The reshaping of the world by hominins subsequently reshapes the *cognitive* economy they inhabit, develop and evolve in.

Niche construction is a view of the evolutionary process that takes seriously the post-Cartesian view of minds; for on this view, changed environments change the evolutionary and selective regimes of individuals (Laland et al. 2000; Sterelny 2007).

This paper explores these ideas with a case study from pre-human cultural history, the emergence of standardised tool forms in the early to middle Pleistocene. It uses the emergence of the first recognisable stone tools as a case study to show how we can reconstruct a new set of cognitive skills by acknowledging that environments shape cognition. Rather than positing that changes in the archaeological record are the result of changes in cognition, it posits that change in tools and their increasing social salience within hominin population changes cognition.

The paper will first outline the evolutionary background of hominin tool use, and then go into some detail into the environmental context of the emergence of stone tools, and their place within human evolution.

In the subsequent section, we will explore some ways in which the ongoing presence of tools within the life of hominins first buffer behaviours, and then become capable of being annexed for further cognitive tasks.

This paper takes the view that minds are not invisible except for some ambiguous clues in the form of enigmatic archaeological remains. This paper takes the view that in a very real sense archaeological remains are pieces of the cognitive machinery of our hominin ancestors.

## The evolutionary background

In this section, we will set out the evolutionary history and the explanatory target for this paper: the emergence of stone tools in the archaeological record. We will start with a brief overview of the hominin species, early hominin tool using, and then proceed to provide and environmental context for the emergence of stone tools.

### The hominids

The last common ancestor of humans and chimps was approximately 5 mya. It is generally thought that the split in the hominid lineage came about due to the increasingly dry conditions of the Pliocene, particularly in the eastern and southern parts of Africa. In these drier regions, we see fossil evidence for the Australopithecines, a classic example being the fossil of *Australopithecus afarensis*, commonly known as Lucy. The number and diversity of Australopithecine species is controversial, as is species and taxonomic designations for the entire human evolutionary lineage (Foley 1991; Kramer 1993; Wood and Collard 2001; Cameron 2004; Cameron and Groves 2004). We will, for the purposes of this paper, sidestep the taxonomic issues, and refer to the Pliocene hominins as Australopithecines, with the early Pleistocene hominins being Early Homo, followed by the Erectines of the early–middle Pleistocene, and finally the Archaic Sapiens (see Fig. 1 for more detail).

With the acceleration of drying trends with the Pleistocene, we see the emergence of Early Homo. Early Homo includes such species as *Homo habilis* and *Homo rudolfensis*. These species appeared at the same time as recognisable stone tools in the archaeological record. The Paranthropines are a sister group to Early Homo. The

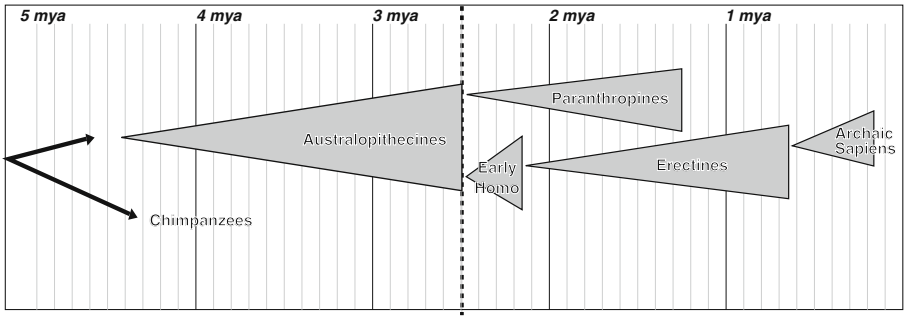


**Fig. 1** This diagram represents human evolution as a series of adaptive radiations of groups of species. It does this simply to sidestep the complex issue of species designations and taxonomies within the human lineage. The first recognisably bi-pedal hominins were the Australopithecines. The Australopithecines include such species as *Australopithecus afarensis* (the famous fossil nicknamed 'Lucy' was its type specimen) and *Australopithecus africanus*. With the acceleration of drying trends in the Pleistocene, we see the emergence of Early Homo. Early Homo includes such species as *H. habilis* and *H. rudolfensis*. These species appeared at the same time as recognisable stone tools in the archaeological record (indicated by the *dashed line*). The Paranthropines appear to be a sister group to homo, and may be an alternative adaptive response to the increasing dry conditions through eastern and southern Africa. The Paranthropines went extinct as a group. The Erectines, the grade after early homo, were notable for their expansion beyond Africa, being found throughout the temperate regions of Eurasia. The Erectine body size also reached that of modern humans, and to all intensive purposes, the Erectines, while physically robust, were physiologically like us from the neck down, but with a brain size ranging from 800 to a 1,000 cc, significantly smaller that the human average of 1,800 cc. The predominate species in this group is *Homo erectus*, but some authors suspect that the geographical spread of the Erectines and their long tenure and physiological variability indicates a significant number of sub-species or species (Foley 1991; Cameron and Groves 2004). They are associated with an extensive stone tool record of bifacial handaxes. The archaic Sapiens includes *Homo heidelbergensis*, *Homo neandertalensis* and *Homo sapiens*. Developments with the archaic Sapiens are not covered within this paper

Paranthropines appear to be hominins who specialised in eating the tough vegetation that was available during the early Pleistocene. The Paranthropines went extinct as a group.

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## The stone tool makers

To understand the role played by tools within the cognitive economy of Early Homo and Erectines, we need to have an insight into the evolutionary context of the tools themselves.

In a 1964, Nature paper, Louis Leakey named a new hominid species *H. habilis*, with the fossil specimen OH7 as the type specimen. OH7 was an important find in its day for a number of reasons; but at the time, it was also the earliest species designated *Homo*; man. Descriptions of species for the purpose of taxonomy normally focus on anatomical and physiological details, or in recent times, genes. Leakey's designation of the *Habilis* fossils as *Homo* was in part based on a presumed relationship with stone tools. Tools, quite literally, makes the *man*, on Leakey's view (See Tattersall 1995 Chapter 8). Tools were an evolutionary novelty that allowed for an inclusion in the *Homo* genus.

We now know that Leakey's view was wrong. Tool use has now been documented over a number of species, from the specialised tools of New Caledonian Crows (Hunt and Gray 2002) to occasional tool use in animals such as Otters. Tool use is not particularly diagnostic of some unique human capacity. Crucially for us, tool use is probably a hominid homology, as our only closest living relatives, the chimps, produce a variety of culturally learnt tools (Whiten et al. 1999). As such, tool use is not diagnostic of the Homo genus, nor of some fundamental 'humanity,' simply because they are not evolutionary novel developments that arrive with *H. habilis*.

What's more, the hominoids (all large primates) engage in long extractive foraging sequences. These extractive foraging sequences involve steps that prepare the food, either through peeling, pounding or some other preparatory action (Whiten et al. 2009). With this in mind, tools such as the ant fishing sticks used by Chimpanzees are thus additional preparatory steps in a behavioural sequence or chain, and not something unexpected or novel (see Fig. 2). Tool use of this kind is continuous with their known capacities and foraging patterns.

Given this background, we can probably assume that the Australopithecines were tool users in the Chimp mode as well. In all likelihood, the use of tools, and the cultural learning of useful extractive foraging sequences, was probably an important capacity that allowed the Australopithecines to survive.

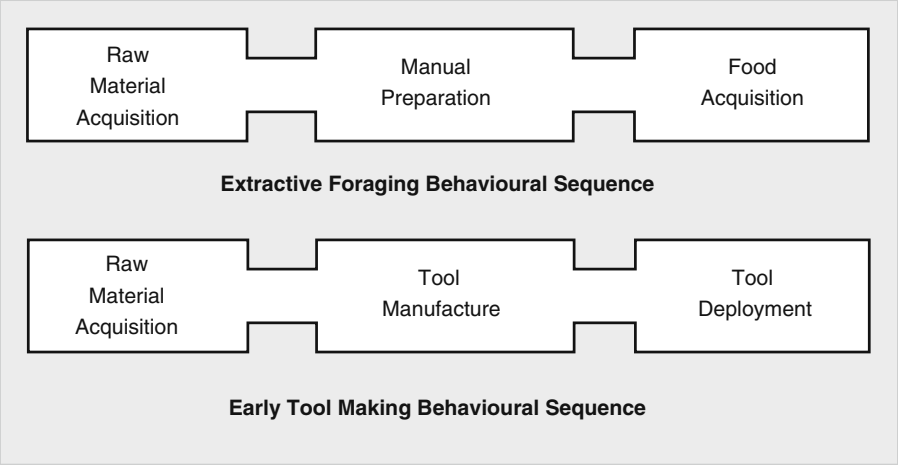


**Fig. 2** Many behaviours are long-chained sequences of actions. So, the Hominids (chimps and bi-pedal hominins, including *H. sapiens*) all engage in extractive foraging behaviours, where food must be prepared in a number of stages before being consumed. Tools, particularly the disposable 'one use' tools of primates, can be seen as a component in a foraging sequence

So, Leakey's transition, the emergence of Homo with the emergence of *H. habilis*, does not represent a revolution in hominin cognition with the sudden appearance of tools. *H. habilis* undoubtedly had tool-using ancestors; it is just that the tools used by those ancestors were disposable and probably indistinguishable from naturally occurring objects.

However, Leaky was not entirely wrong in highlighting the existence of tools as an important part of the lifeways of Early Homo. For the relationship between hominins and their tools was changing due to the sheer fact of the day-to-day presence of tools in their environment. *H. habilis* might not have been the first hominid to make tools, but it was the first one to have tools that lasted, and that might be have been used more than once. It was the first hominid to perhaps start having an adaptively crucial relationship with a tool. It is that relationship that we need to explore; the shift between the temporary and disposable to the permanent and reusable.

### *Mode 1 and mode 2 tools*

The earliest tools are of course rather simple. Early Oldowan tools, sometimes referred to as Mode 1 tools due to their manufacturing method, are simply rocks with flakes struck off. In the earliest cases, either the core or the flake could be the tool. It is only later with the developed Oldowan that we see the core itself emerge, with proto bifaces; cores with flakes removed from both sides. The use of the tools is not certain, but it seems most likely that the flakes were used for de-fleshing carcasses, etc., while the cores were used for long bone smashing and extraction of marrow. Mode 1 tools are typically associated with Early Homo, from about 2.5–1.8 mya.

Subsequent to mode 1 tools, we see the emergence of the distinctive Acheulean handaxe at approximately 1.8 mya. These tools are sometimes referred to as mode 2 tools, as the manufacturing method is distinct from Oldowan tools. Generally, a large flake would be removed from a cobble, and this flake would be trimmed to a fairly standardised shape. In fact, while there are subtle differences in manufacturing methods in mode 2 tools, they show a remarkable consistency across time and space, with the only significant change being an increase in the level of finish in tools (McNabb et al. 2004; Lycett and Gowlett 2008; Sharon 2009). We will return to the issue of increased finish later.

This tool probably played a variety of roles in extractive foraging sequences, but most likely their predominant role was in assisting in scavenging activities. The scavenging may have been aggressive and confrontational in some instances. Bands of hominins armed with branches, noise, and perhaps rock throwing, could potentially drive off satiated predators from their kills (Young 2003; Plummer 2004). The Erectines quite probably engaged in some active hunting. They were at least part time members of the predator guild (Plummer 2004).

Tools then were important components in the foraging activities of early homo and the erectines. They allowed access to parts of carcasses that other predators could not get to (Schick and Toth 1993) and they were necessary for their subsistence strategies in a way that the tools of chimpanzees are not. Tools at this point in human evolution are increasingly important parts of the hominin world. They are quite probably vital to the survival of early and middle Pleistocene hominins, and in a very real sense, becoming increasingly cognitively salient as a result (Fig. 3).

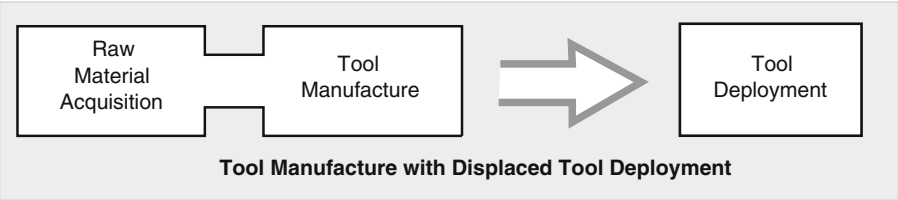


**Fig. 3** Tool using in Early Homo and the Erectines required that the tool manufacturing task and the deployment (foraging) task become decoupled from direct stimulus (see Jeffares 2010 for more detail)

## The ecological setting of tool use

The Pliocene and subsequent Pleistocene represents the acceleration of a drying and cooling trend in eastern and southern Africa. However, we have to be wary of seeing the result of this as the definitive appearance of the modern east African savannah of television documentaries, or the semi-desert scenes of "Early Man" shown in the opening sequence of the film "2001: A Space Odyssey."[2] In fact, even today, the environment of these areas is patchy and highly variable. Open areas are interspersed with areas of shrubs and trees. A waterway might be fringed with acacia woodlands; thorny bush areas might cluster around an escarpment of rock. This mosaic of habitats was not only on a local scale, but on a continental scale as well. The lifting and rifting of the east African landscape created rain shadows that might aggravate drying, but also that encouraged relatively moister areas on the windward side (Vrba et al. 1995).

This patchy landscape was never stable, even over the short time spans of decades. Elephants in modern Africa are key shapers of the environment (Owen-Smith 1989). They knock down trees to get at tender shoots, and create clearings that form the basis for grassy areas. These areas are then slowly re-colonised by trees, but in a predictable succession of plant types. Without elephants and other large browsers, eastern Africa would in fact be forested, and the consequent mix of browsers and grazers would be different. There would undoubtedly be similar cycles of modification and change throughout the Pliocene and Pleistocene.

Whilst the Pliocene was comparatively stable seasonally, over the course of the Pleistocene from 2.5 mya, seasons became increasingly variable, with dry and wet periods, and distinct changes in flora and fauna depending on the time of year. This encourages the movement of browsers and grazers across the landscape in seasonal patterns, and forces non-migratory organisms to have flexible, seasonal diets.

The emergence out of Africa by the Erectines (or possibly even Early Homo) suggests even more variance within the ecology of hominins, but this should not be overstated. The pattern of glacial and inter-glacial cycles increased through the Pleistocene, so while it is true that Erectines were in areas such as the southern United Kingdom, there were hippopotamus in the Thames estuary at the same time

[2] Our image of 'wild' pre-human Africa is of course shaped by the fact that, like many countries, the game reserves and parks of east Africa, where the nature documentaries are all filmed, are in areas marginal for agriculture. This view of Africa as a dry environment is further aggravated by the needs of film crews tracking animals. Film crews prefer open environments that enable them to get shots with long lenses at safe, unobtrusive distances. Important elements of the East African biome such as closed acacia forest or thorny scrubland are not ideal documentary making environments and consequently rarely feature in the mass media portrayal of this part of the world.

(Pitts and Roberts 1997; Stringer 2006). The glacial inter-glacial cycles may well have allowed the geographical spread of the Erectines along with other African species, but equally, they may have contracted their geographical range as temperatures cooled. It is, therefore, not clear whether the geographical range of the erectines shows their capacity to adapt to many different habitats, or whether they expanded and contracted with their favoured conditions.

*Increasing variability and range size*

The upshot of all this is simply that our hominin ancestors were living in patchy and mosaic environments that were constantly shifting. Environments differed over the course of the year, over the course of generations and over evolutionary timescales. To make a living in such environments, hominins had to travel, to move across the landscape, traversing ecological zones. Hominins might forage in one environment, and perhaps seek refuge in another. Hominins are tied to water sources, for their cooling relies predominantly on evaporation (sweat), so reliable sources of water would have to be a part of their home range. Estimates as to home range size are widely varied. This is to be expected as different populations or groups would inhabit different circumstances, and these home ranges would of course change over time. Nevertheless, despite these differences, we can expect that average travel within home ranges to have been in the tens of kilometres, and home ranges to be significantly bigger than those of chimps. Homo then had to navigate this complex world, and learn to use it. They had to recognise signs of a potential carcass hidden in the undergrowth, potential sources of water, the possibilities of raw material sites and the dangers of certain environments. As the hominin's world became patchier, increasingly diverse, larger, and temporally inconsistent, static cognitive maps of their world would need to be constantly supplemented by the ability to utilise more ephemeral and fleeting signs and signifiers of what the world contained. Hominins had to start using the world and its cues in increasingly rich and complex ways.

## The mobile ape

Tools, as noted, were undoubtedly part of the early homo foraging repertoire, and probably became crucial components with the Erectines. But with the increased ranging of pleistocene hominins, it would unlikely that raw materials would be consistently ready to hand. It becomes necessary that one have a tool *in hand*, preparatory to possible use.

It follows that tool manufacture must be decoupled from the immediate stimulus of a foraging opportunity (Fig. 3) (Jeffares 2010). Tools must be made in anticipation of need, and this may represent the emergence of mental time travel, as suggested by Thomas Suddendorf, Michael Corballis and others (Suddendorf and Busby 2005; Suddendorf and Corballis 2007).

However, our interest here is not the cognitive preconditions of tool curation, but rather, what tool curation meant for hominins. How might the constant need for a tool and its constant presence in the lives of hominins have changed the way they thought? At this point, we need to step back from the details of evolutionary history, and think about how the constant presence of tools, and objects in general, can play a role in our own cognition.

## Tools as foci and signallers

Hominins were living in complex worlds, with shifting ecological zones and new threats and opportunities available as they moved through the world. But while they had to retain flexibility, they also had to stay on task. They could not wander at random through the environment acting as purely reactive organisms (Godfrey-Smith 1996). They had to have goals other than dealing with the immediate environment. If an individual's home range did not contain readily available raw materials, then they needed to make a strategic decision to look for raw materials. During travel, they might need to make a short term, expedient decision to divert to a location that looked to have a water supply, or perhaps be forced to divert due to carnivore activity. The patchy world that Hominins inhabit and traverse forces them to juggle short-term needs, long-term goals and objectives and immediate problems.

Wayne Christensen has suggested that individuals move between different levels of awareness in accomplishing just these sorts of complex tasks (Christensen 2009). Christensen's suggests four categories of awareness: Firstly, one has a model of self and one's capabilities. Secondly, one has an idea of the strategic task, the ultimate goal of the current activity. Thirdly, an individual must have an awareness of the current situation, a situational model. Finally, a motor control model is necessary to simply move through the world (see Fig. 4). Christensen is in part building upon ideas developed within aviation psychology, where pilots have to divide their attention between various tasks such as navigation, communication, the monitoring of the aircrafts mechanical systems, and the actual motor control skills of flying.

Whatever one may think of the detail of Christensen's taxonomy of levels, the general point is well made; attention must shift between various aspects of the world. One must monitor the world as one navigates through it, and have in mind a final destination. An individual might need to know what they are doing at that particular moment in time, but equally, understand how this sub-task fits into the broader picture of the project. Faced with short-term distractions, one needs to be able to deal with those distractions, but then move swiftly back to the accomplishment of the strategic goal.

### Tools and awareness

In moving between various levels of awareness, the act of engaging with a tool is significant in itself. To some extent, it helps to keep one on task. The difference between the slung and the carried rifle, or the strung and unstrung bow, are not just differences of convenience The carried rifle promotes a habit of mind, and level of awareness that is distinctly geared towards its use. Features of the landscape take on new salience, physical habits are modified for silence, and so forth.

There are parallels here with mantras for sports people. Again, the phrase "keep the eye on the ball" isn't about representing, or even, apparently, about keeping one's eye on the ball (Sutton 2007). In discussing the extended mind and embodied action in relation to the playing of cricket, John Sutton suggests that such phrases help elicit an automated habit: a chain of action, or a psycho-physiological discipline (Sutton 2007). Such psycho-physiological disciplines as "keep your eye on the ball"

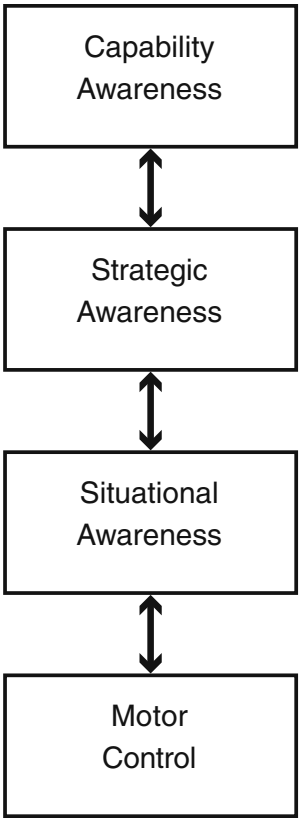


**Fig. 4** Wayne Christensen has suggested that there are differing models that one must refer to whilst engaging in sophisticated tasks. Capability awareness is a model of one's abilities. Strategic awareness is about the ultimate goal of the current activity, and situational awareness is the current state of the world around one. Motor control is the awareness of one's body, and the relevant fine motor movements etc., one might need to complete a task. Individuals move through these differing levels of awareness and control at different points in order to fulfil complex tasks. Regardless of whether we agree with this particular model, the general point—differing levels or types of awareness at different moments during a task—is well taken

will of course be reinforced if batsmen have clear physical foci for the task at hand: the bat and the associated paraphernalia of the cricketer's protective gear.

This use of tools for props for levels of awareness, and for these "psycho-physiological disciplines" carries over into preparation. The act of tooling up for an activity shapes one's awareness, and helps one prepare for, and plan for, the task at hand. Experienced sportspeople use the processes of gear preparation as mechanisms for settling heart rate, planning and preparing their minds for the physiological and psychological co-ordination tasks that lie ahead. And it is not just sportspeople who do this. Craftspeople of all types use the act of preparing the tools for an activity as an act of psychological preparing as well. Many academics, likewise, annotate margins and underline key points when reading papers as an aid to focus and as an aid to task concentration. The practice of highlighting in books is often less about creating a reminder in the text that can be used for later retrieval, and more about creating a physical emphasis in the act of reading.

*Stone tools as foci*

Once we recognise these roles for objects and tools as ways of focusing our minds, and keeping us on task, we can begin to see a new interaction emerging with stone

tools and the cognitive skills of early homo. Initially, early Homo was probably an opportunistic forager, making tools on demand as the occasion arose. But this tool manufacture became an increasingly important part of the hominins world; so much so that it is probable that our hands and musculature have adapted to accommodate the grips necessary for tool manufacture (Marzke 1997, 2002; Marzke et al. 1997; Tocheri et al. 2003).

Early Homo did not range as far as later hominins did, and it is likely that it could build a home range around shelter and water, and forage within this area. But as tools became increasingly important, a component of that home range had to be a supply of raw materials. Moreover, the raw materials and tools had to be carried, as it is unlikely that raw materials for tools and foraging opportunities were in the same place. Early Homo had to carry tools. They had to be part of what they moved through the world with. Frequently, tools would be carried independently of actual need, and carried in anticipated need.[3]

Tool carriage, in this context, acts as a potential anchor in an array of possible tasks. They assist individuals in staying on task by their physical presence. Within Christensen's levels of awareness, they help individuals stay on the strategic task, and potentially, help individuals overcome distractions.

So there is a feedback loop here; tools are necessary parts of the day-to-day tool kit of opportunistic scavengers, but they also potentially act as cognitive buffers for staying on task as hominins traversed their patchy environment in search of sustenance. What am I doing now? I have a tool in my hand. Am I prepared? Do I have that familiar heft of a tool on my person? I have a tool, how can I use it? Tools potentially assist in task awareness and reinforce confidence in confrontational situations, just as individuals seize weapons when confronted with potential threats.

Tools at this point in the human lineage are then playing a role in shaping the adaptive niche of hominins (see Sterelny 2010). But that changing niche is not just a changing physical feature of the world. Tool use, the ubiquitous need for tools, and tool carriage scaffolds cognition in ways that actually extend hominin cognitive capacities. At this point, the extension is an increased ability to engage in tasks with a strategic payoff, as the tools act as a buffer to working memory and a cognitive *aide memoir*. This in turn may well feedback into a selection for increased working memory itself (Suddendorf and Busby 2005; Suddendorf and Corballis 2007). Nevertheless, it is helping to play a working memory like role by being part of a community of users.

However, whilst the early stages of tool use buffered and supported cognitive processes, this would change quickly, for Hominins are highly social, and highly interdependent, organisms. Once this use of tools as a personal buffer is in place, and once tools are ubiquitous features of the hominin world, they also become available for social use. Tools become signals.

[3] This is likely to have differed from place-to-place, as raw material availability would have differed. A group that habitually foraged along a watercourse might never need to carry tools, as raw material was in constant supply. Nevertheless, the ability to carry tools potentially broke early homo's dependence on raw material sources, allowing range expansion.

## Social signalling

During my post-graduate study, our department used to go to drinks after the departmental seminar. But there is always someone who needs to quickly do something in his or her office before we set off. And of course, people need to retrieve bags, coats and other materials from their office. In such a situation philosophers, like other academics, succumb to the lure of briefly checking their email whilst waiting for others. The result is a set of false signals are sent and received. Everyone is in fact ready to go, but we all look like we are working as we fill in time checking our email, awaiting everyone else. People start moving once impatient individuals start sending a new signal by standing in people's doorway, clearly ready to go.

This example illustrates an important point: we make decisions about the world based on our appraisal of others. What's more, this appraisal can in turn be based on their accoutrements. Compare the individual who appears at your office door carrying their bag and dressed for the brief walk to the end of the week staff drink, with the individual who appears at your door prepared for a pick-up basketball game, dressed in athletic gear and carrying a ball. The social role of an individual, the functional role of an individual, and the immediate concerns they have are often conveyed by what they carry, what they are wearing, and their relationship with their equipment. Uniforms, regalia, mode of dress, and equipment all matter. And so does an individual handling of their equipment. The individual fumbling with unfamiliar equipment does not inspire the confidence of the seasoned professional and their casual ease with the necessary gear for the forthcoming task.

If tools are adaptively salient for individuals, and we have every reason to think that they are, it will pay to have one. What's more, given high levels of co-dependence with fellow hunters, it will pay to have the kind of mind which tracks whether or not other people have tools as well.

In such environments, people are engaging in signalling games that should quickly converge given certain conditions (Skyrms 2004). And in the tool using case, there most likely are just those conditions for convergence. To see this, take the modern situation of scuba diving. Divers do a buddy check to ensure that their dive partner is properly equipped with the appropriate gear. Buddy checks are not just about ensuring the safety of one's companion. By ensuring that they are equipped properly, I ensure the smooth running of the dive for us both, and more importantly, I also ensure they have the relevant safety gear to save *me* should things go wrong; and vice versa. There is a clear convergence of interests for everyone involved in a buddy check that the appropriate gear is in place and functioning.

For hominins, hunting or even aggressive scavenging most likely revolved around group effort, and good co-ordination across individuals. As a participant in such a potentially risky activity, it pays to ensure your comrade in arms is in fact armed. Paying attention to his readiness in this regard is likely to have significant payoffs. The party member who leaves without a tool is, while not useless, a weak link. They may even be partly dependent upon others. It pays *me* to ensure that *you* are not going to mess up our collective hunt, or our group activity. Like the divers' buddy check, there is a clear convergence of interests here; a moment of absent-mindedness has potential implications for me, and my comrades. Everyone benefits from making sure we are all equipped appropriately.

Such behaviours also police potential free riders on any gains made from joint activity. Individuals can assess the commitment of others prior to engaging in joint activity by assessing the upfront investment in the relevant gear and the general preparedness of others. The individual who turns up to the fishing expedition without fishing equipment is a freeloader. In situations where equipment minimises personal risk, the poorly equipped are a potential hazard.

Stone tools, when viewed in this context, become constantly meaningful. In the hands of others, they actively begin to signal important information about one's fellows. They indicate preparedness, competence and perhaps even status. They are honest signals of upfront investment in the capability for joint actions, and thus indicate integrity and potential for honest dealings. The presence (or absence) of a tool becomes a cognitively salient feature of the hominin social world.

Tools, and the curation and carriage of tools, can thus slip from being buffers for personal behaviours, into being signals. Tools take on a life independent of field deployment. They take on a signalling role, and become extensions to our assessment capacities. They become incidental, but highly communicative, offloads of the character traits of an individual to one's tool. This is particularly true where tools remain a high investment item.[4]

Tools, weapons and objects can even indicate attitudes and emotional states. To hand you a knife handle first is not only polite, it contrasts markedly with me pointing one at you.

## The Acheulean

So how does all this fit in with the stone tools of early homo and the erectines? Perhaps it illuminates the following curious facts associated with the later Acheulean: late mode 2 tools are often overwrought, and on some occasions, not even used (Kohn and Mithen 1999; Kohn 2000). In fact, many late Acheulean tools are virtually unusable, with some giant handaxes being too large to handle.

Marek Kohn and Steven Mithen argue that this over investment in tool making is because the social signalling role of tools has become increasingly important. They suggest that tools actually become signallers of prowess and competence, but that this signal is being used in sexual selection (Kohn and Mithen 1999; Kohn 2000). They argue for sexual selection on the basis that tools signal resource competence (knowing where there are raw materials), physical competence (handaxe manufacture) and by being major investments in time, they act as handicaps, signalling an excess of resources that demonstrate fitness (Zahavi and Zahavi 1997; Hawkes and Bird 2002).

The idea that tools play a role as sexual signals perhaps overstates the case. But we should take seriously the broader point that tools act as important signallers of

[4] In our modern world of disposable incomes and the casual acquisition of goods, a high value piece of equipment does not necessarily indicate high levels of competence. No experienced diver or freediver mistakes an expensive diver's watch for competence in the sport. Nevertheless, the mere fact of having genuinely relevant equipment demonstrates some level of knowledge and commitment, even if misplaced. The honesty of the signal is then very much dependent on its production costs, and in environments without disposable incomes, investment in equipment is an honest signal.

competence, for as we saw above, competence matters to many individuals in the community, not just potential mates. In such circumstances, tools move from being foci for individuals as they go about their tasks, to foci for the assessment of one another. They become a means by which individuals can assess one another, and in turn, a means to signal with. Consequently, investment in tools is a way of demonstrating to others one's capabilities and capacities. In such an environment, investment in tools is an investment in social signalling, as much as it is a functional need, for its important to be clear to one's community of one's ongoing commitment to joint activity. An investment in a tool is an investment in one's identity within a group.

## The dual life of tools

Tools then play three roles within the cognitive economy of Early Homo and the Erectines. One, they help maintain a personal level of awareness during activities. So they assist an individual in remaining focused on strategic goals in a world without immediate stimulus, and in moving through a world of distractions. Secondly, this very utility at the personal level signals to members of a group; we can read off the readiness of other group members from the relevant equipment. We can also use the equipment of others to help us retain focus. This in turn makes further investment in tools worthwhile as a mechanism to communicate one's capabilities. The result is a feedback loop that reinforces the behaviours, both at the level of the individual, and at the level of the group.

What's more, because they grow up in a world of tool users, tools become part of the developmental world of young hominins. Just as my builder neighbour's sons play with builder's tools—imagined, plastic and sometimes real—so too one would expect young hominins to grow up incorporating proxies for tools, even if sticks and stones, into their play. This would build habits of use, and habits of using tools as individual and social props. Who am I now? I am a hunter. How can you tell? Because of what I hold in my hand.

So, tools structure the cognitive environment not only of the makers and users of tools, and not just to their immediate peers; tools are likely to structure the informational environment of the successive generations of hominins as well (Odling-Smee et al. 1996, 2003; Laland et al. 2000; Laland and Brown 2006; Sterelny 2007). A young hominin's world is a world of tools, tool use and tool manufacture. Consequently, their cognitive world includes tools as a buffer for behaviours, and as social signals.

Consequently, tools start to play a role in the world of hominins that is ubiquitous in modern environments. Cultural products—tools—signal, buffer, and become available as means for reading the capacities of others. In a community of individuals such as the Erectines, who were without full language faculties, tools become important communication devices. Objects we are familiar with become signals and communication devices associated with their usage. So, in a noisy party, I can ask you if you want a drink by waggling a bottle in the direction of your empty glass. You can say no by covering it, preventing access. The mimicking of the activities of pouring and denying access is a gestural language enhanced by the objects themselves. For a pre-linguistic or partly linguistic

species such as the Erectines, this was potentially an important extension to their communication capacities. To present a junior apprentice member of a group with the equipment standard among full and accepted members is a signal that is easily recognised, and powerfully communicative.

It is worthwhile noting briefly that there is no cognitive module being advocated here. I am not arguing for an encapsulated, specialised cognitive skill, such as nativist Evolutionary Psychologists might argue for (Cosmides and Tooby 2005; Buss 2004; and see Jeffares and Sterelny Forthcoming for an overview). Tools simply are a regular feature of the world, and as such, they become available as proxies for their makers, and as props for day-to-day activities, in the same way that our car keys might, or a tennis racket.

This section's main point has simply been that once tools are present in the lives of hominins, they become available as props and signallers for cognitive tasks. They play an active role in the mental life of hominins. Tools are not quite acting as full offloads of cognitive content in the sense originally advocated by Andy Clark and David Chalmers (1998; Clark 2008), but they are being actively manipulated as cognitive tools. It is the beginning of a relationship with material culture that goes beyond the pragmatic, and becomes more cognitively elaborate with time. We have gone beyond the traditional view of tools as extensions of hominins' physiological capabilities. Rather, we are seeing tools as extensions to our ancestor's cognitive capabilities.

## Conclusion

This paper has laid out a trajectory for the co-evolution of hominins and their tools. In particular, it has shown how the continued presence of tools in the world of hominins changes the cognitive possibilities of tools. Once tools become persistent features of the hominin's world, they can become active components within the cognitive economy of hominins. Tools become capable of playing multiple roles within the hominin world. Initially, they prop and scaffold the behaviours of individuals. Because of their visible presence within a community of makers and users, they act as social signals of status, competence and readiness. When gestured with, they add emphasis and potentially even novel content. So tools over time not only buffer behaviours, they also act as reliable signals of capabilities and intentions. As a consequence, tools contain information that individuals cannot fake.

The evolution of these capacities and these increasingly rich roles for tools is a co-evolutionary one, in that it depends as much on the evolution of the culture as it does on the evolution of the organism. Because young hominins grow up in environments where stone tools are ubiquitous, the manufacture and curation of stone tools changes the selective environment of hominins. Stone tools became a stable feature of the hominin world, and as such, young individuals can learn and develop in a world with stone tools playing roles within the cognitive economy of the community at large. The picture that emerges is one squarely within the niche construction view of cognitive resources (see Sterelny 2010), with individuals adapting to a world modified by their ancestors.

We started off this paper with a traditional view from cognitive archaeology; the idea that cognition comes first, and the cultural product comes second. But our

analysis here suggests much more complex relationships, as the ongoing presence of tools in the hominin world can in fact change cognitive possibilities. The detectable archaeological record is not just the by-products of hominin cognition; it is in a very real sense a crucial part, and in some cases a cause, of hominin cognitive processes.

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