6SSEL045 – Language Origins
Lecture 6
Tools & Cognitive Complexity

One marker of cognitive complexity that has left its mark in the fossil record is human tool culture. Stone survives for sufficient time to allow us to see how it was used millions of years ago: we are able to look at broken stones and determine whether they were deliberately or accidentally broken; we can tell, through a range of techniques, when they were broken; and we can use increasingly informed inference to determine what they were used for after breaking. From this process we have come to understand the development of tool-making in the hominin clade, in terms of what was produced, how it was produced, and for what it was likely used.

We should also be aware that several different suppositions are at work here: first, we assume that the dating techniques are reliable; second, we assume that there was reason and purpose behind the stone-breaking, and those reasons were practical and not artistic; third, we infer likely uses for the broken stones; and fourth, we extrapolate from these assumptions to the cognitive processes behind the making and using of the tools. Nonetheless, the stories being told about tool-making and tool use by our ancestors seem to be evidentially reliable.

Useful terminology about dates: *BP = Before Present; mya = million years ago; kya = thousand years ago; BCE = Before Common Era (equal to BC); CE = Common Era (equal to AD).*

NONHUMAN TOOL USE

Before looking at human tool use we should remind ourselves that we are not the only species to use tools -nor even the only species to make tools. As well as examples given in previous lectures, six examples of nonhuman tool use are worth listing.

- New Caledonian crows are known for their tool skills in captivity, but they are equally adept in the wild. One of their common habits is grub fishing – poking sticks into holes in wood to spear and pull out grubs. There are several methods used, but individual crows habitually use only one of the methods (Hunt & Gray, 2007).
- We have known for some time that chimpanzees crack nuts using stones, but we now know that many other species use stones to crack hard objects – for instance, capuchin monkeys also use stones to break open nuts. However, they do not use any available stone, they select a stone with the best weight to do the job (Visalberghi et al, 2009).
- Figaro, a Goffin's cockatoo at the Veterinary University of Vienna, spontaneously made a pokestick to push a pebble he wanted close enough to the mesh of his cage to grab it with his beak. When tested with food, he made more pokesticks and successfully got the treats. This behaviour is not known in the wild, and seems to have been an innovative technical solution created by Figaro (Auersperg et al, 2012).
- Another behaviour not seen in the wild is string-pulling by bumblebees (Alem et al, 2016). The research team initially tested naïve bees, and a small number spontaneously learned to pull the string to receive the nectar reward. Most others learned when given stepwise training. The trained bees were then able to train other bees by example, so string-pulling became a cultural meme.
- Sea otters are another species which have developed a hammering skill using stones, in this case to open shellfish; this has been known since the late 1960s. However, instead of placing the food on an anvil stone and hitting it with a hammer stone (as capuchins and chimpanzees do), they place an anvil stone on their stomach as they float in the water, and then hit the stone with the shellfish. This means that the shell breaks, but the contents are not pulverised (Fujii et al, 2017).
- The final tool-use behaviour given here involves crocodilians (Dinets et al, 2013). One Indian species and one American species have both been seen under bird breeding colonies with sticks across their snout. When the birds come down to collect the sticks to add to their nests, they instead become dinner.

These tool-using behaviours show that the range of tool-using species is wide, and not limited to a single evolutionary clade. They also show that tool use seems to be a fundamental part of evolutionary foraging strategies; it is not something special that nonhumans learn laboriously as a completely novel behaviour.

TOOL USE AND LANGUAGE

So what is it about tool use, whether by humans or nonhumans, that makes it language-like? There are five features that seem to match well with human language:

- Both tools and language are instrumental extensions of the self, used to achieve the self's objectives; tools work in the physical environment, language in the social environment.
- Both tools and language need to be used in particular ways; a misused tool will not have the desired physical effect, and misused language will not have the desired social effect.
- Both tools and language require a knowledge of sequenced events; if the physical actions or spoken words are not in the right order, the desired effect is not achieved.
- Both tools and instances of language (utterances and sentences) can be part of a larger sequence: tools can be part of a toolkit, and utterances can be part of a discourse or text.
- Both tools and language become the process; particular productive processes cannot happen without the tools, and certain types of productive communication cannot happen without language.

However, tools and language are analogues, they are not the same thing. They differ in one highly significant way: tool use does not need negotiation toward meaning. The tool either does the desired task or it doesn't; it has no ego which can be engaged with on the task.

Using tools may be part of the reason why our languages work the way they do, but that does not mean that tools must be part of the reason why we have language.

TOOL MAKING

While tool-making is now recorded in several living species, the deep history of tool-making in the hominin clade is evidenced only in the stone fossil record. Few tools made of more perishable materials have survived, and none before 500kya. Although it is likely that any tool-making behaviours in modern nonhuman hominids would have been available in the early species of the hominin clades, we have evidence only of stone toolmaking. These stone tools fall into five groups, representing different levels of manufacturing sophistication.

- The earliest-made tools come from a single site, Lomekwi in Kenya. They also seem to be the least sophisticated: sufficient has been removed from a stone to provide a sharp edge, but there is no sign of attempts to improve the edge. It may be that this technology was discovered accidentally: stones used as hammers to break open scavenged bones may have occasionally splintered, and the resulting sharp edges proved better at breaking the bones. The Lomekwi tools are larger than most later tools, and do not seem to have been curated (kept for later use after manufacture). The set is dated to 3.3mya.
- The next tool set is called Oldowan, after the Olduvai gorge in Tanzania where they were first found. Oldowan tool assemblages have since been discovered in Asia and Europe – everywhere that early Homo reached. The earliest assemblage has been found at Gona in Ethiopia, and date to 2.6mya. This is too early for Homo, so it is now believed that Australopithecus (A.garhi or A.africanus) was the first species to develop the technology, and

early Homo borrowed it from the australopithecines. Oldowan tools are still quite unsophisticated – the sharp edge remains the key feature – but there is evidence that the sharp edges were adjusted to work better before use, and then sharpened during use. There is also some evidence that the tools were curated between uses.

- The third tool set is called Acheulean, after the discovery site of St.Acheul in France. The Acheulean tool set is both the first novel stone technology developed by the Homo clade, and the first to include an aesthetic quality into the production: the classic teardrop shape of the tools indicate that the makers were after more than a sharp edge. Marek Kohn (1999) has suggested that the capacity to produce symmetrical teardrop-shaped tools was, for Homo erectus, an indicator that the toolmaker was dextrous, and so good at surviving and thriving that he had time to spare for non-vital activities. Producing the tools was a costly signal of the individual's fitness. It is also possible that this method of tool-making allowed non-displaying individuals to feed first: producing the Acheulean axe also produced a wealth of sharp flakes, which were probably more effective at butchering an animal than the axes themselves. While the first Acheulean tools were found at St.Acheul in France, the earliest Acheulean assemblage, dated to 1.76mya, was found at West Turkana in Kenya, very close to Lomekwi.
- The fourth tool set is called Levallois-Mousterian (L-M), after Levallois-Perret and Le Moustier, both in France. The tools are dated to 160kya, which is somewhat arbitrarily considered to be the start of the industry. Homo sapiens was still limited to Africa at that time, so the L-M industry is usually attributed to Neanderthals – although it was later adopted by the incoming H.sapiens. It is notable that the end of the L-M coincides with the extinction of the Neanderthals. The emphasis of L-M technology was on small, sharp blades designed for a range of different purposes: cutting, punching holes, scraping, drilling, sawing, pinning, to name a few. The larger blades were probably used as spearheads and, although many superficially have an Acheulean teardrop shape, they were produced by a different technique. There is good evidence for extensive curation of the tools: they had a long-term role and not just a short-term purpose.

The beginning of the Metal ages (about 6kya) marked the end of the Stone Age; but between 30kya and 6kya, a lot happened. Nomadic pastoralism (following the herd) probably began about 15kya, giving a tribe continuous access to meat. Agriculture began about 13kya, giving access to a range of foods and removing the need for the tribe to follow the meat. Large sedentary populations resulted in fixed habitations about 8kya. However, as language was already well-established during the Mesolithic (20ya-8ka), none of these events help us to understand language origins, so they will not be discussed further here.

ADVANCED TOOL-MAKING

When we look at tool-making, two key requirements stand out:

- The tool-maker must have the capacity to plan a final object based on the raw material and a cognitive template.
- The tool maker must have the ability to transform the raw material into the final object, adjusting the plan during the transformation.

The first of these is a cognitive capacity, the second is both cognitive and kinaesthetic. There is evidence that Australopithecus had the necessary kinaesthetic skills for tool-making – their hands were similar to ours (Skinner et al, 2015), and they appear to have been capable of both the power grip and the precision grip. We cannot know whether they had the necessary cognitive capacities, but there is some evidence that they did (Semaw, 2000); which is why we are able to attribute the Oldowan industry to them.

It used to be thought that the Acheulean period of tool-making was technologically stagnant despite cognition increasing apace; but it is now recognised that the technology did become increasingly sophisticated over time (Goren-Inbar, 2011), with (somewhere in that period) the appearance of tools constructed from multiple components, such as spears (Wynn, 2009). By the time H.heidelbergensis was replacing H.erectus (about 600kya), it is likely that several of the behaviours traditionally associated with language (multi-material tools, clothes, jewellery, and possibly even art) were being performed by H.heidelbergensis.

Tool making does require innovation, and it does seem to generate further cognitive innovation in a virtuous *monkey-see, monkey-think, monkey-plan, monkey-do* cycle; but, like using tools, it does not need to be socially interactive, and it requires no negotiation toward meaning.

FIRE & COOKING

Another candidate for cognitive complexity is fire. There is evidence that we began to use controlled fire at 1mya (Berna et al, 2012); and Gowlett & Wrangham (2013) argue that opportunistic use of fire – using natural fires rather than setting them – began even earlier. Fire gave us several advantages which allowed us to alter our genetic trajectory and our environment; it turned out to be an excellent niche-construction mechanism.

- **Fire allowed us to cook our food**, allowing us to have smaller guts and simpler dentition (Wrangham, 2009). Cooked food provides a rich diet which is easily digestible; this reduces the amount of energy needed for digestion and, in turn, allows the saved energy to be used for cognitive development.
- **We used fire to alter the landscape** (Bleige-Bird et al, 2008). This meant that we could adjust our environment to favour ourselves and species useful to us, while suppressing those species useless or dangerous to us.
- **Fire let us produce better tools**, by hardening stone edges and charring wooden spears into charcoal-reinforced points (Brown et al, 2009).
- **In terms of the origin of language, the main advantage of fire is that it creates a cultural centre to a group** (Weissner, 2014). A fire acts as a comfortable and safe place to gather: it keeps people warm and predators away; it requires patience while the food cooks, providing time to socialise; and it is a physical sign of grouphood, with an in-group place near the fire, and an out-group place beyond the circle of firelight.

However, while fire is a clear facilitator of social communication, it does not, by itself, explain how or why our social communication got so complex. It can promote the usage of language by providing opportunities for dialogue; but it cannot explain how lexis and grammar emerged.

WHAT ABOUT GATHERING?

It is tempting to take the view that tool-making made us masters of all we survey –and the word "masters" is deliberately chosen: there is a certain "butchness" to making tools which seems to make it a masculine activity. There is some evidence that, in terms of hunting, this may well have been the case; but it needs to be remembered that the contribution to a group's calorie budget from non-hunting activities was equal to or superior to that provided by hunting. Gathering is just as important as hunting, and it has its own technologies. Today, the global economic system means that, for the vast majority of males, hunting isn't even on the agenda; and for the few who still take themselves off to the "wilderness" to shoot something, what they bring home are trophies, not food. It is time to remember that the cognition behind hunting is not the same as the cognition behind tools, and the cognition behind tools is not gendered.

Three types of regular gathering are carried out by modern chimpanzees: honey gathering, plant-related gathering, and insect gathering. Only rarely have chimpanzees been observed scavenging meat, and never fishing (although they gather algae from water using sticks). Orang utans have occasionally been observed spear-fishing. However, a big difference between humans and other primates is that humans habitually gather for others as well as themselves, while other primates gather only for themself and occasionally for offspring.

Human gathering replicates the behaviours of all the other primates, but we also use a wider range of tools. Humans use digging sticks to gather underground tubers; sharp blades to scavenge meat; heavy stones to break bones; simple traps to catch small animals; nets and hooks to catch fish; and smoke to sedate bees when gathering honey. Most of these tools and techniques have been used since at least 500kya, as part of the late Acheulean tool assemblage.

WHAT HAPPENED WHEN?

If we look at our species history in terms of tool-making, and then compare it to our language readiness (see lecture 1) and our brain size (see lecture 5) we can see key facts emerging.

- The Lomekwian industry occurred before our communication system became significantly different from that of chimpanzees and bonobos, and when our brain size was only averaging 475cc. It would appear that you don't need exceptional intelligence or language to develop a tool-making industry. However, as the Lomekwian industry is limited a single location and a short period in the fossil record, it may be the case that you need exceptional intelligence or language to establish a cultural tradition to preserve the industry over the generations.
- The Oldowan industry started when our brain size increased to about 700cc, but before our earliest guestimate for language origins. This may be because language was not needed to establish the Oldowan industry, or it may be that our earliest guestimate for language origins is wrong. However, the Oldowan industry does coincide with both the appearance of the double grip, offering extra dexterity, and the guesstimate for breathing control, the first of the set of physical attributes needed for speech. By the end of the Oldowan period we were probably using complex gesture and expressive facial signalling. However, this does not mean that the Oldowan industry facilitated these movements toward language; there could be an as-yet unidentified process which lay behind both tool-making and language-making.
- By the beginning of the Acheulean we would probably have been using simple, languagelike communication, and our brain size was about 900cc. By this stage we were well on the way to modern language. The guesstimate for the controlled use of fire occurs in the middle of this period, but it does not correlate with tool industries or language events, despite the considerable effect it must have had on both. However, it does coincide with a dramatic increase in brain size – a more than 50% increase to modern sizes. It is likely that controlled fire led to cooked food, which allowed gut size to reduce, brain size to increase, and cognition to become even more complex.
- The Mousterian, a Neanderthal industry, reminds us that we are not the "pinnacle" of human development, just the last species standing.

COGNITIVE COMPLEXITY MAKES COMMUNICATIVE COMPLEXITY?

About 64kya, humans in Africa invented the bow and arrow combination, the most complex composite tool of the Palaeolithic. It quickly spread across the human-occupied world, although it never reached Australia. It may have played a part in the demise of H.denisova and H.neandertalensis, and possibly even H. floresiensis. It probably changed human hunting from the organised pursuit of larger game with throwing spears to more individual smaller-game hunting. It would therefore have affected the communal feasting and sharing which (even today) hold hunter-gatherer bands together. The larger groups would have splintered into family units as the cooperation needed to provide food reduced.

The bow consists of two components: a springy wood branch and a woven string. The branch must be of the right length and width to flex smoothly. The string consists of strips of plant woven together to give a torsional strength, looped at each end, and tied and glued. The glue is made from plant juices and beeswax, and the string is attached to the branch by notching the branch at each end, and putting the loops of the string onto the notches. The string needs to be slightly shorter than the branch to ensure the branch is slightly bent and held under tension. Now you can start making the arrows …

All this technological complexity resembles the complexity of language: they both require semi-automatic cognition to make them work; in both of them, all the parts are necessary to the whole, but there is no obvious relationship between the parts, the whole, and the function the whole performs; both rely on social conventions to be useful; both rely on teaching and learning for the knowledge to be passed down the generations; and so on. However, it is very unlikely that the complexity of the archery kit generated language complexity, or that language complexity produced technological complexity; instead, both products seem to rely on a more general cognitive complexity driving them both. Neither language complexity nor technological complexity is a real "thing"; they both seem to be emergent effects from a non-specific general cognitive complexity – which may itself be an emergent effect of increased brain size.

WORKING TOGETHER

What we can see from the history of tool-making is:

- Tool-making by itself is fairly commonplace; by itself it cannot be an explanation for the origins of language.
- Tool-making does, however, promote working together in joint ventures to gain the benefits of scale and specialisation.
- This, in turn, relies on joint attention to a task: on one side, we must be able to engage the attention of others toward a problem; on the other side, we must be able to take the viewpoint of another and understand what they are seeing as a problem.
- Joint attention allows us to work together in our enterprises and our communication, adopting other viewpoints in the first step toward negotiation toward meaning. Reliability and trustworthiness become key features of our interactions.
- Joint attention also allows us to engage in more productive teaching and learning: communication is no longer just telling another individual what to do, it is involving them in the process as part of the process.
- All of these ways of working together lead us toward Ostensive-Inferential communication: we are no longer just signalling, we are incorporating models of the receivers in our signals, and incorporating models of the sender in our signals received.

How we work together is examined in more detail in lecture 8.