The Coevolution of the Hominid Brain and Tools

Steven Jon Elmore
Department of Anthropology
California State University, Chico

Abstract

The coevolution of man's neural structures and his tool traditions has been a constant point of investigation since the time of Charles Darwin. Here I will look at evidence demonstrating this positive correlation and readdress this point of study with some new evidence from archaeological sites in Africa that have yielded both hominid crania and tools. In addition to the above I will look at the possibility of hand preference as early as the australopithecines and early members of the species *Homo habilis*, who some feel is our earliest ancestor, as opposed to *Australopithecus africanus*.

Throughout the history of the discipline of Paleoanthropology the relationship(s) between man's brain (crania) and his tools ("culture") has been a point of constant inquiry. At the turn of the century the brain's expansion was given much credit as a prime mover in hominid evolution. Charles Darwin felt that tool use was both the cause, and effect of, bipedalism. Darwin's Tool and Adaption Theory contended that ape like "protohominids" elaborated upon early tools and thus became more reliant upon them. This, in turn, led to an elaboration of the brain that brought about an increase in the complexity of tools. The hand was freed when bipedalism arose and the labor of the hand brought about other changes leading to further perfection of the hand and the further development of the brain (Frederich Engels: 1896). Another influential figure in Physical Anthropology, Raymond Dart, felt that australopithecines had the cognitive abilities to make and use tools made of bone, horn and teeth, "osteodontokeratic culture".

Today there are many who feel that brain and tool elaboration are interrelated in a positive correlation with one another. I shall cite the work of these individuals (e.g. Sherwood Washburn, Philip Tobia, Nicholas Toth, David Pilbeam, *et. al.*) later in this discussion.

What I contend is this: As the hominid brain became more developed, so did man's tool assortment (or "tool kit"). While I shall primarily concentrate on the early formative stages of human evolution (australopithecines to *Homo erectus*) this data has much farther reaching implications, both biologically and socially.

TOOLS AND MAN: A POSITIVE FEEDBACK CYCLE

Sherwood Washburn (1960) in his article Tools and Human Evolution set forth a framework describing the effects and consequences of both tools and brain evolution. Early in the study of man it was held that man evolved to almost his present state-then discovered tools. This is now known to be false. Washburn contended that early man (running bipedal, small brained ape man) had already learned to make and use tools. The advent of tools would forever change human history. Washburn states:

> It was the success of the simplest tools that started the whole trend of human evolution and led to the civilizations of today.

Tools would change the pressures of natural selection and thus the form of man. Washburn felt that tools are responsible for changes in hominid teeth, hand, brains, and pelvises. Tools accomplished these changes in morphology, in part, via biosocial influence. Imagine, if you will, a group of early hominids that were using tools to defend the group. The role of group protection was initially related to large canines in males which were used in group defense. Hominid's small canines are biological symbols of a changed way of life; their functions replaced by tools. It is appropriate to note that some have extended this argument to include Ramapithecines as tool users based upon their lack of large canines.

Sherwood Washburn (1960:73) further supports his argument with the following citation:

> ...it is the area of the brain that deals with the thumb in humans that is enlarged, as compared to modern apes. This corresponds to our greater manipulation of the hand.

This citation illustrates the general format of the comparative study of the hominid brain and his tool's complexity.

Briefly, I shall describe the basic tool types, or "traditions", that I shall later refer to.

The concept of and "Osteodontokeratic Culture" was first posed by Raymond Dart. Quite simply put, this is a technology based primarily on the manipulation and utilization of bones, teeth and horns not stone(s). Commonly associated with the australopithecines, this technology, unfortunately, is almost impossible to distinguish from faunal remains in the archeological record. Philip Tobias (1971) feels that there is a definite association between osteodontokeratic culture and australopithecines. He cites the following evidence: an extreme number of specific bones in sites associated with australopithecines, such as Makapansgat, evidence for a cultural preference for specific bones and bone fragments; the absence of carnivore tooth marks on bones; many long bones show evidence of damage to the extremities before fossilization; many recurring shapes of tools/bones; differential wear patterns on bone flakes...

Stone cultures would have immediately followed osteodontokeratic culture(s). The respective date range for stone tool cultures are as follows: Oldowan, from _circa_. 2 m.y.a.; Achulean, from 1.5 m.y.a.; Mousterian, 150,000 B.P.; Aurignacian, 50,000 to 7,500 B.P.; Soultrean, 32,000 to 20,000 B.P.; and Magdalenian, 20,000 to 7,000 B.P. (Toth 1987; Washburn 1960).

Oldowan tools are perhaps the oldest stone tools presently known to man. These tools, sometimes called "pebble culture" are characterized by the crude flaking of rocks to form choppers, scrapers and crude hammerstones. These implements were probably used to get the marrow of bones and/or general bashing tasks. Primarily unifacial Oldowan tools are commonly associated with _Homo habilis_ and perhaps _Australopithecus boisei_/"Zinjanthropus". The primary research with this technology dates it back to _circa_. two million years ago (Leakey 1966).

Acheulean tools were the next tradition to evolve. Characterized by hand-axes and cleavers, the Acheulean tradition gives rise to the first unquestionable bifacial tools. This tool type is commonly associated with _Homo erectus_ and is represented in such sites as Ambrona and Torralba, Spain. These two sites are widely believed to have been specialized hunting sites (Butzer 1965).

Zhoukoudian is also associated with _Homo erectus_ and Achevolean tools. Zhoukoudian is located in The People's Republic of China, near Peking. This site has, and continues to, yield much information about _Homo erectus_, including the possible use of fire and the appearance of ritualism. Here we find evidence of the possible use of bone and stone tools. The accusation as to the bone tools is based upon the site's high yielding of the bones of a specific species of animal, nineteen _Megaceros oachyosteus_. The most common tool found at Zhoukoudian was the hammer (47) followed by scrapers (10), points (9), bruins (3) and choppers (Binford and Ho 1985).

Mousterian tools were the next to appear. Mousterian tradition tools consisted mainly of drills, a variety of scrapers, denticulates ("tooth-edged") and Levallois flake tools. The Levallois flake of "prepared core" techniques consisted of three basic steps: First, a core was prepared into a shape on one side corresponding to the shape of the flake desired from the core. A large flake was then removed and then the prepared flake was removed. The Levallois flake is one of the main cultural transition markers between the Lower and Middle Paleolithic. It is estimated by some that this technique is roughly twenty times more efficient than Oldowan and five times better than Acheulean tools, as measured by the amount of cutting edge per surface area produced by each respective technique.

STUDIES MEASURING TOOL COMPLEXITY

One of the most perplexing tasks at hand when one wishes to actually (numerically) analyze hominid tool data is the basic question of: HOW? Should this be done via weight, length, width...? Any of the previous methods is far above my means as an undergraduate. I would no doubt have great difficulty in attempting to conduct a numerical analysis of hominid tools, for the resources are simply not at hand for me to do this myself here at CSUC. Fortunately, some studies as I am contemplating have been conducted. Within Ralph L. Holloway's article <u>Culture, Symbols, and Human Brain Evolution: A Synthesis</u> (1981:295) I have found reference to two men's studies on the increasing complexity of hominid tools over time, A. Leroi-Gourhan and S. A. Semenov.

Leroi-Gourhan's study utilized the measurement of the length of various tools' cutting edges. His results indicated a steady increase in the amount of cutting edge on hominid tools over time from an established constant of 1 kilogram of rock. The results ranged from 40 cm. of cutting edge for an Oldowan pebble tool to 10 m. for the complex blade tools of the Upper Paleolithic (Aurignacian: Soultrean...).

The study conducted by Semenov took a somewhat similar approach to the study of stone tools in that the amount of work involved in tool manufacture was the primary point of measure, as opposed to the amount of cutting surface/area. The amount of work involved was measured by the estimated number of blows/area of rock required to make the given tool and also the phases or stages involved in the tool's production. The results were as follows: Oldowan tools involved perhaps 3-4 blows; Chellean Hand Axes, 10-35; Achulean 60-75; and lastly, Mousterian tools, 100 blows involved. Acheulean tools required two phases of manufacture: a roughing stage with a hammerstone and a finer, more refined stage for detailed work. Mousterian may have required of some four plus phases of manufacture.

These two studies clearly demonstrate a gradual increase in complexity of tool manufacturing techniques over time. As I shall demonstrate, this elaboration in cultural tradition(s) is paralleled by an increase/elaboration in man's brain.

BRAIN EVOLUTION/DEVELOPMENT

Tool making eventually brought about the advanced hominid brain via selection pressures, about 1.6 m.y.a. Some other factors were also positively selected for: inter/intrapersonal relationships; communication; cognition and the sexual division of labor (Blumenberg 1983).

Philip Tobias (1971) set forth five general bodily structure and function requirements for tool making: the size and complexity of the brain; learned patterns of behavior; stereoscopic vision; a prehensile hand capable of precision gripping; the freeing of the forelimbs via sitting or bipedalism. All of the above can be attributed to early australopithecines. Tobias contends that indeed australopithecines were capable of a tool using/making culture, but did they? Tobias, as many others do, feels that it was Homo habilis who first used stone tools and that the australopithecines probably utilized an osteodontokeratic culture. I quote Tobias (1971): "Australopithecus learned to exploit his mind's abilities that in time his descendents would depend on it.'

There are four main, specific anatomical/functional features associated with the hominid brain that are important to our discussion. The first is the multiplication of units (cells) via mitotic division (hyperplasia); growth of the units themselves (hypertrophy); relative brain to body size ratio. The last criteria in the theory of Tobias is that the human brain is very hominidized (complex) on the interior, leading thus to more complex behavior (Tobias 1971; Holloway1981; Blumenberg 1983).

For our purposes there are three main brain characteristics that can be deduced from the archeological record of fossilized hominid crania: the volume of the endocrania; the asymmetry of the cerebral hemispheres and the patterns on the endocast of the crania left by the brain's cortical convolution patterns.

First of all, and most notable, is the increase in cranial capacity in humans over time. As can be seen in the chart below, there has been a steady increase in cranial vault volume, as well as the range of variation among individuals of a population (Tobias 1971:98;30).

RESPECTIVE CRANIAL CAPACITIES FOR VARIOUS PRIMATES

SPECIES	CRANIAL CAP.	NUMBER IN SAMPLE
Chimpanzee	393.8 CC.	144
Orangutan	411.2 CC.	260
Gorilla	506.0 CC.	653
A. boisei	530.0 CC.	1
A. robustus	500.0 CC.	1
A. aficanus	494.0 CC.	6
H. habilis	556.0 CC.	3
H. erectus	859.0.CC.	6
H. sapien(s)	1350 CC.	1000's

As one can see there is most definitely an increase over time in cranial vault volume. While some of Tobias' sample populations were small, his results were similar to other's studies. In summary, from the australopithecines to modern humans we have seen a three fold increase in the volume of the hominid brain.

Ralph Holloway (1981) has cited five variables associated with the expansion of the cerebral cortex: Nerve cell size; neuron density; the amount of branching of the nerve cells (dendrites), resulting in more connections (synapses); the glial cell to neuron ratio; and an overall increase in the number of cells present.

One possible measure of innate mental capacities is what some have referred to as the total amount of extra neurons. That is the number of neurons in excess of those necessary for the body to function normally. In the course of hominid evolution (Australopithecus africanus to Homo erectus) we have seen the amount of 'extra neurons' nearly double from an estimated 4.3 billion to 8.9 billion. We also see a higher number of extra neurons in higher primates. A chimp has an estimated 3.4 billion extra neurons, whereas Australopithecus africanus, whom some feel is similar, had 4.3 billion. This trend holds true for a broader comparison of primates (Tobias 1971). **(SEE CHART ONE/APPENDIX FOR A MORE DETAILED COMPARISON OF LIVING AND EXTANT PRIMATES).**

Asymmetry of the cerebral hemispheres in man is another indicator of neurological function. Tobias (1971) felt that australopithecines demonstrated a pattern of left occipital; right frontal petalial asymmetry. This, he felt, is indicative of right handedness, as it is in modern humans.

The role of the brain's general anatomy, as well as asymmetry, was crucial in a study of early hominid tool usage and production conducted by a young experimental archeologist by the name of Nicholas Toth (1987). Toth's work was conducted at Koobi Fora, Kenya, as well as Olduvaai Gorge. While his work there was unique these sites had previously been examined by Mary and

Louis Leakey; Glynn Issac and Jon Harris, of the University of Wisconsin.

Around 1.4 to 1.9 m.y.a. these sites were savannah grasslands and occupied by two distinct species: Australopithecus boisei, a small brained hominid with a dentition specialized for a vegetable diet. The other was Homo habilis ("Handy Man"), a gracile; large brained omnivore. These species were determined by skulls produced in beds one and two, Olduvai Gorge. Post cranial remains of Homo habilis also demonstrated a hand capable of relatively great dexterity, enough to make and use stone tools.

In addition to the hominid remains, tools of the Oldowan and Acheulean (developed Oldowan) traditions were found. Just who made the tools was the puzzling question at hand. Homo habilis was declared the most likely candidate based upon his unspecialized dentition (their function perhaps replaced by tools) and his demonstration of hand manipulability (Leakey 1966). With regard to the possible phylogenetic relation(s) among these two species Leakey (1966) notes:

> "...the comparative speed with which (it is inferred) the Homo line evolved from a gracile ancestor similar to Australopithecus africanus, while Australopithecus robustus/ boisei remained biologically unchanged until overcome by competition, can only be due to skillful tool making and use originated by the gracile form."

In regards to an ancestral form of "handedness" among our hominid ancestors, Toth (1987) found evidence of handedness in patterns of unifacial flaking-distinguished by the pattern of cortex, or weathered rind, on the surface. Most species of animals are equal in numbers of right handed individuals to left handed individuals. Humans, however, are predominately right handed by a ratio of 9:1. Toth, in his duplication of the tool production techniques employed at these sites found a ratio of 56:44 right to left handed flakes. He attributes this to his right handedness. The assemblage at Koobi Fora yielded a right to left handed flake ratio of 57:43 - Lateralization of the human brain had apparently begun.

CONCLUSION

As one can plainly see from the presented evidence there has been a positive correlation between the increase in neural complexity and the elaboration of man's tools. It has been stated that these two variables in hominid evolution were very likely involved in a positive feedback cycle. As man developed a more elaborate tool kit, his brain had to become more elaborate for their production and utilization. This increase in cranial capacity in turn led to an increase in the ability of man to make more advanced forms of tools. He was now, for instance, able to form mental templates to more efficiently manufacture his tools and he also now had a greater ability to pass this knowledge down from one generation to the next, thus shortening the learning time required for tool manufacture. As was stated earlier in this paper: it was the first tools made by man that started the chain of events that would lead to the civilizations of today.

APPENDIX

[Chart 1]

Neural Ratios Among Primates

SPECIES	CRANIAL CPCTY. cc.	BODY SIZE cc. ths.	TOTAL NEURN bil.	BODY NEUR bil.	EXTRA NEURN bil.
Chimp	400	45	4.3	.9	3.4
Gorilla A	540	200	5.3	1.8	3.5
Gorilla B	600	250	5.7	2.1	3.6
A. Boisei	530	50	5.2	1.0	4.2
A. robustus	500	45	5.0	.9	4.1
H. habilis	680	35	6.2	.8	5.4
H. erectus	900	50	7.4	1	6.4
H. sapiens	1300	60	9.5	1	8.5

FROM TOBIAS (1971:111)

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