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The Origins of Language Seen in Lithics and Cerebral Asymmetry

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The Origins of Language Seen in Lithics and Cerebral Asymmetry

The evolution of language is a central issue in archaeology. While many methodologies have been used to address the question of when and how language originated, few have focused primarily upon handedness in lithics. Lithics are the most abundant and well-preserved element in the archaeological record and can offer insight into hominid behavior. In this paper, lithics, as understood experimentally, are presented as primary evidence for handedness, which is related to cerebral asymmetry and language capacity.

Introduction

Understanding prehistoric hominid intelligence is essential to the field of archaeology. The possibility of seeing cognition in lithics, an abundant and reliable set of data in the archaeological record, is enticing. Combining the research of various archaeologists, primatologists, anthropologists, and others leads to a connection between stone tools and cognition. Presumably, if one is able to determine a dominance of one hand over the other in a species, one can assume, based on the work described below, that the cerebral hemispheres of an individual of that species are asymmetrical. Handedness, a cross-population bias towards use of a specific hand, is unique to humans. Right-handedness has dominated the human species for thousands of years; the determination of the origin of this is critical for this hypothesis (Corballis 1997: 715). This asymmetry has been linked to language development; most areas of the brain relating to language are found in the left hemisphere, which also controls the right hand. Lithics, when used in conjunction with primate studies, endocasts, and more, offer a reliable source of evidence for handedness in the archaeological record. This is not only due to their abundance. Hominids are the only group for whom the forelimbs are used primarily for something other than locomotion. This activity, flintknapping and use of stone tools, must have been of importance and ubiquitousness in prehistory (Frost 1980: 449). Stone tools also
offer information concerning hominid decision making ability and problem solving
(Schick, Toth, and Garufi 1999: 821). However, the interpretation of lithics in studying
handedness requires the use of experimental archaeology to determine what handedness
would look like in artifacts.

**Review of Published Literature**

**Archaeological Evidence for Handedness**

Lithics are an excellent source of information about prehistoric behavior. Excepting for geological and biological agencies, stone tool artifacts are only affected by
hominid interaction. If an archaeologist accurately controls for taphonomy, the way in
which hominids created and manipulated lithics should be clear and the corresponding
cognitive abilities should be apparent (Toth 1987: 763). However, certain things must be
accounted for before interpretation of stone tools is accurate. Taphonomy, raw material
morphology, and possible selection on flakes must be considered. Once they are
controlled for, lithics may serve as a window into past hominid behavior (Pobiner 1999:
90).

The history of lithic analysis relevant to the study of handedness dates to the 19th
century. In 1890, de Mortillet, one of the pioneers of French prehistory, claimed that a
majority of Paleolithic scrapers, a type of tool common especially in the Middle
Paleolithic, were more comfortably held in the left hand. From this, he concluded that
hominids of the Paleolithic must have been predominantly left-handed. Shortly after this,
in 1896, Brinton examined North American bifacially-flaked lithics and argued that the
asymmetry of these artifacts derived from the preferential left-handedness of their
manufacturers (Toth 1985a: 607). More recently, the *chaîne d’opératoire* has been
utilized, primarily by French archaeologists, in explaining early hominid intelligence capacity in general. This does not relate specifically to handedness and the cognition leading to language ability, but the issues are closely entangled. Scholars such as Pelegrin have argued that the complexity of production of lithics, added to the variability inherent in the process, in terms of raw material, gestures, and so forth, necessitated a constant reevaluation of the situation at hand and an essentially modern ability for decision making and imposing a mental form onto physical material (Pelegrin 1990: 117). While *chaîne d’opération*, matched with refitting studies, does have potential to reveal handedness in the archaeological record, it has not been extensively used in such a manner as of yet. The history of handedness studies in anthropology has persisted through the modern day. In 1991, Coren and Halpern published an article in which they claimed, not uniquely, that left-handed individuals are likely to die younger than right-handed ones. This argument for decreased survival fitness in left-handed people was based on the percentage of left-handers in various age groups. Coren and Halpern showed that the older age groups, at a maximum of 80 years old, had a marked lower percentage of left-handers than younger groups, with an age minimum of 10 years old, did. Naturally, many cultural pressures must be considered in this evidence; in older generations, left-handedness was discouraged and seen as a weakness in children. Even when this is considered, the decreased survival ability hypothesis sparked controversy as much of the public, particularly the left-handers, was alarmed at the prospect of a nine year life expectancy difference, as calculated by Coren and Halpern. Coren and Halpern explained the difference with a greater accident risk for left-handed people, but this idea
has fallen out of favor as the dominance of social pressures on modern handedness has been explored (Harris 1993: 203-217).

In modern studies of lithics and handedness, the evidence is hardly overwhelming. There is little direct evidence, and most of it is based on experimental work, such as the experiment by Toth described here in the section: Potential for Information from the Archaeological Record. Indirect bits of evidence for handedness in lithics include a study which determined that hand preference in modern humans is most pronounced in the task of hammering, even more so than writing. The implications of handedness having a long evolutionary history directly related to flintknapping, which is based largely on hammering ability, is intriguing, though hardly substantiated (Toth 1985a: 612). Other explanations have been based on the inherent asymmetries of flintknapping. A flintknapper must hold the hammerstone in his dominant hand, typically the right, as this hand is responsible for the skill element, and the non-dominant hand must steady the core using nothing more than a powerful grip (Toth 1985a: 610-611). However, there is little proof that modern methods of flintknapping, completed in this fashion, were utilized in the Paleolithic.

Handedness has also been studied in Paleolithic art. Archaeologists have pointed out that most prehistoric handprints are of the right hand, while most hand silhouettes are done of the left hand, suggesting that they were painted with the right. In addition, most animal profiles were drawn facing left, which is the typical and natural style of modern right handed artists (Pobiner 1999: 90). However, this same orientation evidence was first used by Wilson, in 1891 to show that artists were preferentially left-handed (Toth 1985a: 607). Complete studies to resolve this conflict are yet be undertaken.
Handedness as Determined by Environment

Some anthropologists have argued that whether or not handedness can be seen in the archaeological record, it is not of evolutionary consequence because it is not a genetic trait. Studies have shown that there is no simple genetic explanation for handedness and that the incidence of left-handedness in a population is greatly influenced by environmental factors (Phillipson 175-176). Provins observed that classical musicians and similarly skilled individuals learn control over limb movement; it is not inborn. Natural musical talent is a different subject matter, but manual skills are directly correlated to practicing. Provins did admit, however, that this is not a perfect anecdote because the adults under observation gained their basic motor skills in infancy, prior to the development of musical skill (Provins 1997: 556-557). Additional studies have concluded similar points. Provins also pointed out that within the first year of life, an infant uses its left and right hands equally often with an equal skill level (Provins 1997: 556-557). Twin studies, also, have not conclusively shown genetics to be the sole basis of handedness determination. Chance does seem to play a role (Corballis 1997: 715).

Handedness as Determined Genetically

The distribution of handedness is not a bell shape curve as most genetic traits are. Instead, it is a bimodal distribution with a small peak on one side, a larger peak on the other, and little in between. Corballis saw this as evidence that handedness is divided dichotomously genetically, and the few variations, which land between the peaks, are due to environmental pressures. Genetics can explain why handedness of children is correlated with their parents, though environmental factors could affect that as well (Corballis 1997: 714)
Other evidence for the genetic inheritance of handedness relates directly to the brain. The bias for left brain dominance in speech is even higher than that for right-handedness, the hand correlated to the left side of the brain. This indicates that genetics may hold a large effect on this asymmetry (Corballis 1997: 717).

Handedness might have been adaptive because of a threshold level of dexterity required in tool making. However, the emergence of left brain dominance might have been at the loss of right brain skill such as those needed for navigation. The evolutionary implications of this are intriguing and promote the importance of brain asymmetry and language in species evolution (Corballis 1997: 724).

**Relationship between Handedness and Brain Asymmetry**

Gross morphological examination of adult and infant cerebral hemispheres generally indicates a highly significant statistical correlation between handedness and asymmetry of hemispheres (Holloway and La Coste-lareymondie 1982: 101). The development of population-wide preferential right-handedness during hominid evolution appears to be directly related to the emergence of this profound lateralization of the brain. As the hands became more distinct in terms of skill level, each hemisphere of the brain became uniquely specialized for certain functions. Generally, as seen in modern humans, the right hemisphere, connected with the left hand, is focused on spatial perception. The left hemisphere, which controls the dominant right hand, is associated with language skills (Toth 1985e: 607).

Right hand dominance is often considered to be the first step in the evolution of left-hemispheric specialization of the brain. There has been speculation that handedness correlates to an asymmetry in the nerve tracts that innervate the arm and hand. This
connection between hand and brain is revealing when matched with the evidence that right-handed humans are more likely than left-handed people to have wider left than right occipital lobes and wider right than left frontal lobes in the brain. This was demonstrated by Le May and Culebras when they examined the morphology of the brains of forty-four unselected individuals. Within this group, thirty-eight showed the asymmetrical pattern discussed above. In a sample of eighteen left-hand dominant people, however, fifteen demonstrated lobes of the brain balanced in size. Matched with the innervation evidence, this supports the connection between cerebral lateralization and manual specialization (Falk 1980: 76 and Frost 1980: 448). The coexistence of these anatomical elements is very likely related to the fact that speech, linked to the left-hemisphere, involves skilled serial motor activity of the face like that demonstrated by hands (Frost 1980: 455). While many scholars have claimed that handedness is merely an effect of muscular imbalance, it has been demonstrated that lesions to the left hemisphere of the brain, particularly in the posterior region of the parietal lobe, are related to disabilities in the ability to produce complex manual motor sequences (Frost 1980: 448).

Humans are unique in this relationship between handedness and asymmetry of the brain. Frost explored this anomaly and concluded that it is curious that not only are species-wide right-handedness and the correlative asymmetries of cerebral functioning unique to hominids, but that the hominids are also exceptional, in their use of lithics, a form of behavior necessitating asymmetric use of the forelimbs (Frost 1980: 447-448). Primates do show some degree of lateralization, but unlike humans, the directionality of lateralized functions is unstable within large populations and it is not predictably linked to manual preference. This implies that handedness and cranial asymmetry are strongly
connected biological occurrences, and that this is not the case in non-human primates or other species examined so far (Steklis 1985: 167). While primate populations have not empirically demonstrated handedness, they do show hand preference in many instances. While the regions related to cortical asymmetry appear to be ancestral to hominoids, the concrete relationship to handedness appears to be unique to hominids (Falk 1980: 74).

Nevertheless, the connection between handedness and asymmetry is not perfectly direct. While the great majority of right-handed people are left brain dominant for language, well less than half of all left-handed individuals are right brained. Clearly this relationship requires further research (Corballis 1997: 715).

Other Evidence for Asymmetry: Endocasts

Anthropologists have turned in directions other than lithics for evidence of asymmetry of the brain. Historically, endocasts have contributed important data on this question. In 1981, Holloway examined the endocasts of the crania of Spy I, Spy II, Djebel Ihroud I, and Salè and compared them to those of modern humans. Looking at right-handed, modern Homo sapiens, he determined that the pattern is distinctly weighted in the direction of left-occipital and right-frontal petalias and Holloway demonstrated that this pattern held for the four Neandertal specimens. Holloway extended this conclusion of matched asymmetries in moderns and Neandertals back to the australopithecines. In addition, Holloway examined nearly 140 endocasts of pongids and concluded that the pattern is not seen in non-human primates. They may occasionally show petalias, but the specific, human combination of patterning is rarely seen. Holloway's hypothesis, which he admits to be speculative, is that handedness, asymmetry, and the related specializations of symbol processing and visual-spatial integration, are present in all
species from the australopithecines to modern humans, including *Homo erectus* and Neandertals (Holloway 1981: 392).

However, endocasts are not a highly reliable piece of evidence. Endocranial casts can vary with the degree of pressure and imprint of the intra-cranial structures. As early as 1942, Hirschler determined, from his own study of casts of hominids and primates, that distinct visualization of cerebral fissures on the casts were uncommon and precarious (Le May 1972: 11). Taking these precautions into account, and considering the small number of fossils sufficiently in tact to provide a reliable endocast, the quantity of data on asymmetry of the brain from this subject matter is limited. However, the historical focus in anthropology upon brain size and intelligence has maintained the prominence of endocasts in research (Holloway 1981: 385).

**Relationship between asymmetry and language**

Assumption of an inborn cranial asymmetry has dominated current thinking about hominid cognition (Provins 1997: 554). Generally speaking, the concept has emerged that language functions are more strongly represented, in most human individuals, in the left hemisphere, and that the right hemisphere is focused upon non-verbal, visual-spatial tasks. This is an oversimplified view, but it is the commonly held interpretation of cranial, asymmetrical function (Holloway and La Coste-lareymondie 1982: 101). Lithic experts are intrigued by this because flintknapping is a cognitive process that seems to require the interaction of both hemispheres of the brain. The left hemisphere is involved with analytical processes, especially that relating to language and sequential processing of input. The right hemisphere controls complex visual-spatial processes and perceptions of part-whole relations, each of which are critical for stone tool making. Kumura and
others have proposed that the left-hemisphere specialization for speech is a consequence of the evolution of certain motor skills, as are necessary for flintknapping (Olausson 105-106).

Much of the research concerning the connection between asymmetry and language has focused on the effects of lesions and other physical injuries to the brain. Broca, a pioneer in the study of language areas of the brain, focused his work on patients with brain damage and the effect of that on their production of speech. He was not as concerned with a brain-damaged individual's ability to comprehend speech in others. Similarly, Broca was not interested in the degree of asymmetry, just with its direction. However, his research has not only provided explanation of speech production locality in the brain, but has offered a methodology for connecting areas of the brain with function (Provins 1997: 554). This method has been further utilized in the study of human vocalization, in addition to the work by Broca. In most humans, lesions to the left side of the brain have more damaging effects on speech than those to the right hemisphere. This is not true in monkeys where, typically, only bilateral lesions effectively disrupt vocalization. This has led to the conclusion that the human left cerebral hemisphere is more competent than the right in processing and producing vocalized language, which appears to reflect the fundamental hemispheric specialization for dealing with either temporally or sequentially ordered material (Steklis 1985: 166).

The evolution of this connection, and its relevance to handedness and lithic production, and its chronological order has been the focus of much research. Hewes stated in 1973 that cerebral lateralization, tool manipulation, and manual gesture language evolved simultaneously. He suggested that these events all preceded, and paved
the way for, the evolution of vocalized speech (Falk 1980: 72-73). According to Frost, if tool creation and use evolved well before the origins of language, as most archaeologists would agree, then the lateralization of the praxic mechanisms to the left hemisphere may also have occurred in advance of the advent of spoken communication. When the language did appear in hominid populations, it would have naturally situated in the left hemisphere, whose organization was more compatible with its own characteristic processing requirements. Since the development of additional organization in the right hemisphere to support the functioning of linguistic areas would have incurred a cost in the loss of non-praxic organization, the production of language was inevitably evolved by the mechanisms already available in the left hemisphere. If language had somehow evolved without a prior phase of tool behavior, then the cerebral organization for linguistic behavior might have been bilateral in nature (Frost 1980: 455). In sequential contrast, some scholars claim that auditory processing in communication and other cognitive processes drove the evolution of hemispheric lateralization and specialization instead of handedness or other motor-based functions (Hopkins and Morris 1993: 2). The importance of the evolution of communication skills, in any sequence, was critical for the interaction of hominids. It allowed early man to convey more specific information about his environment. It is possible that the vocalizations physically available to prehistoric hominids evolved a symbolism; certain sounds may have represented specific people, foods, localities, dangers, and more (Schick and Toth 1993: 220).

Other Evidence for Language Origins

Cerebral lateralization is certainly not the only piece of evidence used in the debate over language origins. Anatomical features, such as the presence or absence of
the hyoid bone, and behavioral factors, such as acculturation and symbolic ability
expressed in artistic works, all serve to narrow the question of when spoken language
arose in prehistory. Another neural entity often focused upon is the Sylvian fissure. A
Sylvian fissure is formed during the development of the brain. When the brain grows in
maturity, this small area on the lateral surface of the brain does not grow as much as the
adjacent tissue and eventually is covered by these swifter areas of the brain.
Interestingly, the speech areas of the brain lie along the left, and occasionally right, side
of the Sylvian fissures (see figure 1). Because of this, the asymmetry of these fissures in
the right and left hemispheres appears to be related and necessary in language
development (Le May 1972: 13-14). In Neandertals, a group often considered the last
hominid group without modern language ability, the Sylvian fissures, as seen in
endocasts, appear identical to those of modern man. This points to an even earlier origin
of language. Other evidence, relevant to Neandertals, includes anatomical features seen
as necessary for the enunciation of modern language. Many anthropologists believe that
Neandertals were incapable of pronouncing speech because of the flattening of the base
of their skulls and their prognathism. However, according to Le May, many modern
human adults exhibit these same traits and are capable of full speech production (Le May
1972: 14).

Other examination of language origins looks to primates and their apparent lack
of language. However, some primatologists have argued that primate language is far
more advanced than generally believed. In addition, the extensiveness of communication
through gesture in non-captive chimpanzees as well as the ability of captive chimpanzees
to acquire sign language has indicated that human language may have begun in the form
of manual gesture. If this is true, the determination of when speech production was physically possible has less bearing on the understanding of cognitive ability than previously believed. In a different line of thought, investigations have begun into the under-appreciated complexity of monkey vocalization ability. Some primatologists are observing that this form of speech is far more intricate than previously realized. In this case, the evolution from primate communication to that of modern humans may be more of a continuum than a series of critical steps (Steklis 1985: 158).

**When and For Whom Does this Occur**

Handedness, and the corresponding asymmetries related above, is unique to humans in the modern animal kingdom. For example, handedness is quite different in mice than in humans. Collins performed an experiment in which mice needed to reach for food with one paw. The individual mice consistently preferred one hand to the other, but there was no clear majority for either direction. Attempts were made to breed the mice for left or right handedness, and the failure of this indicated a weak, if present at all, genetic element of asymmetry. The lack of dominant handedness was supported by the fact that the placement of the food within the enclosed area affected the choice of hand for each mouse (Corballis 1997: 715). Similar studies have shown the same lack of hand dominance in other animals. However, one species seems to show a similar asymmetry to humans, the parrot. According to Friedman and Davis, most parrots prefer to use their left foot when picking up objects. Right-foot preference is approximately twelve to thirteen percent of a population (Corballis 1997: 717). This is interesting in light of a parrot’s ability to mimic human speech.
When and why did lateralization develop in hominid evolution? Perhaps the need for the asymmetric use of hands in flintknapping led to the evolution of right-handedness and cerebral lateralization (Frost 1980: 447). Whether or not this is true, the evidence at hand indicates that non-human animals lack handedness and modern humans are nearly universally right-handed. Approximately ninety percent of human beings in any large population are right-handed (McGrew and Marchant 1992: 114). To answer this question, or come close, it is necessary to review the evidence from scholars who argue for various stages in evolution as the origin point.

**Primates**

Handedness and cerebral asymmetry in primates has been studied extensively. It has been determined that, in speech, hemispheric asymmetries are present in relation to auditory analysis and perhaps sound production (Steklis 1985: 163). However, this conclusion is not necessarily applicable to other areas of language cognition.

When chimpanzees are examined, as they were by McGrew and Marchant, any constant laterality seen in handedness is to the left hand, and not the right, which differs from human preferential right-handedness (McGrew and Marchant 1992: 118). MacNielage, Studdart-Kennedy, and Lindblom agreed that there is a slight preference for left-handedness in non-human primates. They saw this to be especially accurate in tasks involving visually guided reaching. The authors link this to an evolutionary continuum leading to right-handedness in hominids (Corballis 1997: 717). Although most analytical data agrees that some degree of lateralization exists in primates, particularly chimpanzees, this asymmetry does not remain constant over all types of activities within individuals (McGrew and Marchant 1992: 117). In addition, in chimpanzees, unlike in
humans, consistent handedness is not established until adulthood. It also does not appear
to be inherited, as there is no clear population bias towards one hand or the other. This
information led Boesch to argue that chimpanzee lateralization relates more to the task at
hand than to a general neurally-guided preference. Boesch did point out, however, that
more information is needed to make definite conclusions (Boesch 1991: 542, 557).

Many scientists have examined handedness in primates as a result of posture.
Hopkins and Morris determined that the left-handedness demonstrated in reaching
activities is directly consequential to the postural constraint of arboreal primates. When
arboreal primates were put into non-arboreal conditions, the hand preference was less
dominant and right-hand preference for some activities began to appear (Hopkins and
Morris 1993: 2-3). Other research on great apes has shown that when forced to reach
from a bipedal position, a shift to right-handedness is seen (Corballis 1997: 717) (see
figure 2). Olson agreed with this result and insisted that a forced bipedal position during
testing “facilitates the expression of a hand preference for some animals” (Olson et al
1990: 84, 92). However, one must approach these results with caution, as primates are
not typically bipedal animals. The right-hand preference is likely to be simply a
mechanical reaction to posture, and not an effect of brain lateralization. The extent to
which this can be applied to natural behaviors in primates, or bipedalism evolution in
hominids, is limited. In general, many studies on handedness in non-human primates are
biased. There is a tendency, though not in all research, to compare left-handed
individuals with right-handed ones, and omit those who show no preference. This skews
observations and results dramatically (Hopkins and Morris 1993: 15).
Despite the obvious connection between asymmetry, language, and technology, the empirical research on laterality in tool use in primates is limited (McGrew and Marchant 1992: 114). In 1991, Boesch observed laterality in hand use during nut cracking, with hammer and anvil, by feral chimpanzees. Similar results were found by Nishida and Hiraiwa, earlier in 1982, when studying hand use during arboreal fishing for ants by primates in Tanzania. In 1990, Stein looked at a population of chimpanzees for handedness in experimental tool-related tasks (McGrew and Marchant 1992: 114) (see figure 3). While primates have been observed as using tools in the wild, especially chimpanzees, no stone tool use has been recorded (Schick, Toth, and Garufi 1999: 821). This highlights the prominence of the adoption of lithic production in the evolution of hominid species. Humans are the only species as yet observed to have any interest in the flaking of stones to produce tools. This behavior began almost four million years ago in hominid evolution, and persists to this day in certain hunter-gatherer groups (Toth et al 1993: 82).

Studies have been done on the education of captive primates to create and use stone tools. The pioneering study of this was completed in 1972, by Wright, with an orangutan named Abang. This study inspired others, such as Schick, Toth, and Garufi’s work with Kanzi, a Bonobo (Schick, Toth, Garufi 1999: 821-822). However, one must be careful in accepting the accuracy of these studies. The effect of holding primates in captivity must not be ignored. Boesch, Byrne and Byrne, and McGrew and Marchant, all reported finding no asymmetries in natural tool-use and foraging of wild chimpanzees and gorillas (Hopkins and Morris 1993: 21).
Schick, Toth, and Garufi's work with Kanzi showed an ability to learn and improve flintknapping ability in primates. Kanzi was able to wisely choose certain flakes over others for use purposes (Schick, Toth, Garufi 1999: 822-830). The work with Kanzi was done primarily in hopes of determining when in evolutionary history did the tool use capabilities of hominids and primates became significantly different under similar motivations (Toth et al 1993: 82). The results showed that Kanzi was distinctly inferior to the technological ability of the Olduwan hominids in terms of awareness of flake angle, degree of decortication of cores, size of flakes removed, and quantity of fractures and edge damage (Toth et al 1993: 89). However, handedness was undeterminable because Kanzi, when possible, abandoned the taught method of flintknapping and chose instead to thrown the raw material against hard surfaces to cause them to shatter. He would then select sharp flakes for use (Schick, Toth, Garufi 1999: 822-830)

However, research into primate language abilities and the inherent similarities to human linguistic ability has indicated, as agreed upon by scientists such as Falk, that the evolution of language was long and the transition from primate vocalization and gestural language to our modern speech was a continual evolution, and not punctuated. Falk based this on comparative primate neuroanatomy; she examined the existence of homologous areas of cerebral cortex related to vocal communication in both primates and humans (Falk 1980: 73). However, despite this connection, the timing of and cause of evolution of handedness in hominids is not understood. While some structural asymmetries have been found, and negated by the research in endocasts mentioned earlier, the connection of this to a functional asymmetry is not known (Pobiner 1999: 90).
Australopithecines

If primates are seen as non-handed and non-lateralized, the separation of the hominid and ape lineage is logically a place to look for the origin of these traits. Frost, though without empirical evidence, insisted that there is evidence for right-handed flintknapping as early as the first australopithecine toolmakers (Frost 1980: 447). The related belief that vocal language began prior to the Lower Paleolithic, with australopithecines, was held by Livingstone when he wrote, in 1973, an article entitled “Did the Australopithecines Sing?” Falk agrees with this time scheme, though not the musical element (Falk 1980: 73).

Holloway and de la Coste-Lareymondie applied endocast data to speculate on asymmetries in australopithecine brains. They argued that these early hominids share the pattern of lateralization seen in modern human endocasts, as explained in the earlier section concerning endocasts, and not that of pongids. They do admit the limited quantity of their sample size, but interpret their findings to mean that a modern cerebral asymmetry occurred early in hominid evolution, around three million years ago. The authors believe that these traits were selected for from this point on for the purposed of enhancing specialization for behavioral capabilities including spatial-visual competence and symbol-processing, both skills important and advantageous for early hominid lifestyle (Holloway and de la Coste-Lareymondie 1982: 102).

In a unique argument, Dart claimed, in 1949, that Australopithecus africanaus at the site of Makapansgat, in South Africa, was dominantly right-handed as seen in the depressed fractures consistently on the left side of fossil baboon skulls. Dart believed that these injuries were inflicted by australopithecine “killer apes” wielding clubs in their
right hands when facing dangerous baboons (Toth 1985a: 607). While this argument is rather speculative, it is consistent with the authors above in its support of australopithecines as the first cerebrally lateralized species.

*Early Homo Species*

Oldowan lithics, probably the work of *Homo habilis* or early *Homo erectus*, demonstrate the ability of early hominids to identify platforms and acute angles, which primates are incapable of. The crude nature of Oldowan tools was perhaps not the result of a lower cognitive ability, but simply the consequence of a difficult to manipulate raw material. If this is true, the working of the stone tool was probably completed to a necessary level of efficiency, and nothing more (Toth 1985b: 113). However, others have argued that the mind was clearly limited to some degree in early *Homo*. The variation in stone tools, particularly in the Lower Paleolithic, occurred at a rate as slow as that of biological evolution. This indicates that the progress of the brain was directly related to the progress of efficiency in stone tool production. However, Krantz has claimed that some of the limitation may have derived from physical inabilities of hominid hand morphology. Hand morphology was clearly selected for at some point, and probably related to tool-making ability, once an arboreal lifestyle was abandoned. Once bipedalism evolved, selection would have been for shorter fingers and larger thumbs, as this combination allows for most control in flintknapping. In the archaeological record, australopithecines are seen to have hands near, but not quite at, modern human levels. However, with the emergence of the genus *Homo*, hand morphology matched that of modern humans and, hence, stone tool making capability was only affected by cognitive ability at that point (Krantz 116-120). Schick and Toth argued that Oldowan technology
did represent a new cognitive level, and not simply the advancement of hominid hands. These authors saw an emphasis on planning and foresight in these lithics. This, however, can not be empirically proven. Wynn, instead, saw a significant threshold later, between one and a half million years ago and three hundred thousand years ago. Wynn believed that the geometry of Acheulean hand axes required intelligence parallel to that possessed by modern humans. He claimed that no later advancements in lithic production required a significant advancement in cognition (Olausson 105).

Phillipson related this argument to handedness and argued that the functional aspect of hand axe morphology was related to a dominant right-handedness similar to that of modern human populations (Phillipson 175). Previc also observed right-handedness in lithics beginning around 1.9 million years ago. However, based on the percentage of right-oriented flakes found, right-handedness applied to only two thirds of the population at most (Corballis 1997: 717). Similarly, Toth's experiments observing right and left oriented cortical flakes (described in the section: Potential for Information from the Archaeological Record), led him to estimate that lateralization of the brain occurred in hominid evolution between 1.9 and 1.4 million years ago. His determination of this, based on the Early Stone Age assemblage found at Koobi Fora, Kenya, correlated to the species, *Homo habilis* and possibly *Homo erectus* as well. Toth did, however, consider that *Australopithecus boisei*, persisted until one million years ago, in this area, and possibly contributed to the lithic assemblage (Toth 1985a: 611).

In another, more speculative, line of evidence, some scholars have argued that the persistent efforts of *Homo erectus* to spread into the Middle East implies a social organization signifying an advanced level of linguistic ability (see figure 4). Under this
consideration, language, and hence the corresponding asymmetries, evolved around the
time of *Homo erectus* and no neurological advancements were necessary beyond this
point (Mithen 1994: 32). Beginning near two million years ago, with the emergence of
the genus *Homo*, cranial capacity increases dramatically. This was possibly accompanied
by reorganization of brain structure, as seen in endocast data. This is exceptional from
the australopithocene pattern of no asymmetry of the brain. Schick and Toth interpreted
this to say that these large-brained hominids were significantly more advanced in terms
of intelligence (Schick and Toth 1993: 103). In addition to the increase in cranial
capacity, and possible reorganization, Broca’s area, associated with speech production in
modern humans, appears to be significantly more developed in *Homo*. This implies that
*Homo erectus* and possibly *Homo habilis* possessed ability for speech well beyond that of
australopithecines (Schick and Toth 1993: 220-221). Whether or not cerebral
lateralization was present in primates and early hominids, the expansion of this into full
language did not arise until the genus *Homo* (Falk 1980: 74).

**Neandertals**

Anthropologists rarely identify Neandertals as the developers of handedness and
especially language, particularly in light of the Middle to Upper Paleolithic transition,
described in the next section. However, the relative abundance of Neandertal fossils
provides much anatomical understanding of the language capabilities of this species.
Some researchers have argued that the superlaryngeal vocal apparatus of Neandertals, as
seen in casts of crania, more closely resembled of modern newborns than of modern
adults. These similarities include that the body of the mandible is longer than the
ascending ramus, the ascending ramus of the mandible inclines which leads to a open
angle between the body and ramus, the mandibular coronoid process is broad and the mandibular notch is shallow, the hyoid bone and larynx are high in position, the dental arcade is “U” shaped, the length of the hard palate is the same as or less than the length between the hard palate and the anterior margin of the foramen magnum, and the section of the occipital bone between the foramen magnum and the phenoid bone is near the horizontal instead of inclined vertically. These similarities apparently contrast the anatomy of modern adults. Anthropologists have used this as ammunition in their argument against Neandertals having language capabilities (Le May 1972: 9-10).

Anatomically Modern Homo sapiens

The archaeological record changes dramatically in nature around forty thousand years before present with the beginning of the Upper Paleolithic. In addition to more advanced stone tools, new materials are introduced: bone, antler, and ivory. In addition, personal ornamentation and artistic works become common. Previously unexplored areas of the world, though sometime later, become reachable. This may reflect, as many archaeologists have theorized, a large jump in cognitive ability from a primitive form to an essentially modern capacity. Whallon agreed that colonization of areas such as Siberia was only possible, due to the low density of resources, after fully modern cognitive capacity developed and corresponding social structures were in place (Mithen 1994: 32). With the exception of sub-Saharan Africa, the transition from Middle to Upper Paleolithic was abrupt and punctuated. This implies a dramatic advancement in hominid capability (Foley 1987: 387). Many anthropologists attribute the theory of “one species, one technology” to this transition. Of course, minor variations in assemblages must be overlooked with this idea and only the most fundamental differences considered. With
this hypothesis in mind, anthropologists attribute the transition to the Upper Paleolithic to the appearance of modern *Homo sapiens* in evolutionary history. However, Skhul and Qafzeh, sites where anatomically modern humans are found with Middle Paleolithic industries, contradict this theory (Foley 1987: 390). In general, however, the magnitude of the change of behavior at this time in the archaeological record has led anthropologists, such as Mellars, to question if a threshold of human cognition, in relation to the emergence of language, can be seen here. Mithen agreed “we cannot doubt that hominids with language will behave and leave an archaeological record very different to hominids without language.” However, as seen earlier, there are arguments for an earlier evolution of human language (Mithen 1994: 32). In addition, handedness may have evolved with anatomically modern humans and attributed to their superiority and the consequential disappearance of Neandertals and *Homo erectus*. However, if both arose together, as predicted by the correlation of cerebral lateralization and language, language was likely to be more advantageous than handedness (Corballis 1997: 724).

**Experiment**

**Reason to Experiment**

As stated before, there is a lack of information regarding the existence of handedness visible in lithics. This is an area of study that can be helped profoundly by experimental archaeology. It is nearly impossible to accurately determine what constitutes evidence of handedness in artifacts without the use of experiment. However, experimental research can not directly answer questions about handedness and lithics. Experimental archaeology is limited in its conclusions to what *could* have occurred and can not necessarily explain what *did* occur. Thus, experimental research must be paired
with archaeological data to best interpret the past. This is done best through an
interactive examination of the two sets of data. In the opinion of Amick, Mauldin, and
Binford, archaeological patterning should direct the experimentation. If this is done well,
the comparison of experimental and archaeological information may provide a better
understanding of past behavior, in this instance the possibility of handedness in
flintknapping. This may provide answers, and will likely propose further questions.
Hence, the study must be a continual one; new archaeological data should lead to new
experimental analysis and vice versa. In this light, experimental research is useful and
necessary for accurate interpretation of the archaeological record (Amick, Mauldin, and
Binford 1989: 1).

In hopes of filling, to some extent, the gap of knowledge concerning lithics and
handedness, I propose here an experiment designed for this purpose. This experiment
was not completed for this paper, because of a lack of participants as described below.
However, the plan of the experiment, its analysis, and expected results should hold true to
an actual experiment.

Setup of Experiment

A minimum of two individuals with approximately equivalent flintknapping
experience and skill, one right-handed and one left-handed, are needed. A larger sample
group is preferable, as long as the numbers are equivalent between the two groups. The
participants, referred to as two individuals from here on, would be placed in a constant
setting. They would be equipped with the same chairs, lighting, space, and so forth.
Either simultaneously, or at identical points in the day, they should begin to work the raw
material. The material to be knapped would, naturally, be of the same type, volume, and
preferably the same shaper as well. Each would be equipped with the same hard hammers, soft hammers, and pressure flaking tools. The individual controlling the experiment (the experimenter) would be equipped with an accurate timing device, such as a stopwatch, a video camera in case they fail to observe something, a still photo camera for recording debris distribution (along with something for indicating scale), and a notepad for qualitative observation. Hopefully, with such a setup, all variables excepting for handedness, would be held constant. The nature of the experiment, as it is based on individual activity, would make controlling the variables difficult. For this purpose, a larger sample group, and the repetition of the experiment, would aid the accuracy of results.

**Flintknapping Activity**

The participants would be expected to begin by removing flakes from the core. The more flakes and tools that they can generate, the better, but a minimum of twenty flakes, two types of cores (Levallois and Blade, perhaps), and five retouched pieces (a biface, two blade types, and two scraper types) would be needed. The experimenter would record the time spent by each participant on each product. The debitage would be unmoved, and recorded intermittently by the still photo camera. It would probably be useful for the experimenter to hand-illustrate this pattern as well. Throughout the process, the experimenter would need to qualitatively record observations on ease of flintknapping for the individuals. The experimenter would also be responsible for collecting all the materials in order to quantify the number of flakes produced, percentage of debitage per volume of original raw material, amount of cortex on flakes and tools, size of flakes, size of tools, and size of individual pieces of shatter.
Flake debris is often overlooked in experimental studies, as well as in the archaeological record. However, debitage can reveal important insights into hominid behavior. This phenomenon is becoming increasingly recognized by archaeologists. It is important to examine for many reasons. First, it is available, at least experimentally, in large quantities. Its sheer abundance dominates assemblages. Second, shatter is the resultant of core reduction and retouching by flintknappers. It can therefore offer information about those primary functions. Third, debris is rarely removed from archaeological sites by any human or geological phenomenon. It typically remains in place, far more often than the tools themselves (Shott 1994: 71). However, archaeologists who do examine debitage assemblages share a tendency to critically examine the morphology of individual pieces of material, in hopes of determining specific techniques of production, and do not look at the pattern of debitage spread as a whole (Sullivan and Rozen 1985: 773). In light of this, careful observation of patterns of debris should be considered in experimental lithic studies.

**Analysis**

Reliable statistical examination of the various categories of information resulting from this experiment would be critical. The categories of results are presented here in figure 5. Certain categories would need to be tested for significant differences between left-handed and right-handed participants. These categories are highlighted in bold on the same figure. In order to test for significant differences, a t-test must be employed. If only two individuals participate in the experiment, the quantity of data is probably too low for this parametric test, but for the purposes of explanation, we will assume a sufficient amount of data (Thomas 262). The following is the procedure to be followed
for comparing the two populations in any of the categories included in figure 5. It is assumed that the mean, standard deviation, and variance are known.

1) Calculate "F" to determine if the variance of the populations are equal

\[
F = \frac{\text{larger variance}}{\text{smaller variance}}
\]

\[
df = \text{df for population 1} - \text{df for population 2}
\]

Compare this value of F to the value in the chart in figure 6. If F exceeds this value, the difference is significant.

2) Calculate t and df based on one of the following two sets of equations

If variances are equal:

\[
t = \frac{(\text{mean of } x_1 - \text{mean of } x_2)}{\sqrt{(SSQ_1 + SSQ_2) \over (n_1 + n_2 - 2)}} \cdot \sqrt{(n_1 + n_2) \over (n_1 \cdot n_2)}
\]

\[
df = n_1 + n_2 - 2
\]

where SSQ is the sum of squares

If variances are significantly different:

\[
t = \frac{\text{mean of } x_1 - \text{mean of } x_2}{\sqrt{\frac{\text{variance}_1}{n_1} + \frac{\text{variance}_2}{n_2}}}
\]

\[
df = \left[ \frac{\text{variance}_1}{n_1} + \frac{\text{variance}_2}{n_2} \right]^{\frac{1}{2}}
\]

\[
= \left[ \left( \frac{\text{variance}_1}{n_1} \right)^{\frac{1}{2}} \cdot \frac{1}{n_1+1} \right] + \left[ \left( \frac{\text{variance}_2}{n_2} \right)^{\frac{1}{2}} \cdot \frac{1}{n_2+1} \right]
\]
3) Compare the value of t, using df, to the value in the table in figure 7 for $\alpha = 0.05$. If t exceeds this value, the difference is significant between the two means (Dibble, lecture notes, Spring 2001).

From here, one can determine if the means of the categories are significantly different from a left-handed individual to a right-handed individual. Using this information, one can examine the archaeological record for evidence of lithics falling into one or the other category. While these results are not absolutely conclusive, they do offer a testable method for determining handedness of prehistoric hominids.

**Impracticalities of Experiment**

As was mentioned earlier, this experiment was not performed for the creation of this paper. The primary reason was one of practicality. Many flintknappers are needed in order to obtain reliable data. However, in the time provided, I was unable to locate one even left-handed flintknapper (see figure 8). An alternative concept was to use non-experienced individuals as flintknappers, but this raises many other dilemmas. The question of how to teach flintknapping, without biasing the participants, arose. Learning to flintknap through verbal explanation is difficult and typically unsuccessful. However, observation and demonstration is inherently biased unless all participants are taught by experienced flintknappers of the corresponding handedness. Using inexperienced knappers is also dangerous because of their lack of comfort with the task. Patterson and Sollberger predicted that beginner flintknappers would be more set and fixed by their hand position. Experienced knappers are more likely to follow the geometry of the core itself maintain the flexibility probably felt by prehistoric hominids who relied extensively on lithics (Patterson and Sollberger 1986: 110).
If one is able to locate a left-handed, experienced flintknapper, issues of control of variables become critical. It is exceedingly difficult to guarantee equivalent levels of skill and experience. Varying levels of experience and comfort with the materials is sure to skew the results. A large sample size should help reduce this effect, but it can not be ignored (Patterson and Sollberger 1986: 109). Factors such as these led to my decision to not complete the experiment and to only follow it through as a thought experiment.

**Expected Results and Interpretations**

The results of an experiment such as this can only reveal a limited amount. First, it is nearly impossible, as stated above, to guarantee equivalent levels of experience in knapping. Even the slightest variation to this factor, or to general comfort in the environment, can ruin the integrity of the results. Second, the method of flintknapping used by professionals today and generally interpreted as representative of prehistoric stone tool making might not accurately recreate prehistoric methods. While the methods are likely to be similar, one can not be sure. As Kanzi proved by creating flakes by throwing raw material against the floor, new methods, not conceived by archaeologists, are always possible. Third, it is likely that the sample of flintknappers to experiment with would be too small in size. Left-handed individuals constitute only ten percent of the human population, and the percentage of those capable of flintknapping is small. Fourth, a problem inherent in all experimental archaeology must be considered. This dilemma is that what could have been true in prehistory might not have been true. This extends beyond flintknapping methodology and applies to all areas of experimental research. Proving that one could have used a certain technique to create something seen in the archaeological record does not prove that it was used. Last, this experiment can not
provide data directly on language processing. The connection between lithics and language must be determined through other methods as seen in this paper.

For results typical of an experiment of this kind, one can look to Toth’s 1985 experiment. Toth determined, through experimental work, that right-handed knappers tend to produce statistically significant higher proportions of right-oriented cortex flakes. These are secondary flakes partially covered with cortex, with the remaining cortex oriented toward the right lateral edge (see figures 9 and 10). The orientation considered here is with the proximal end of the flake held upwards. This result relies on the belief that right-handed knappers tend to remove flakes in a clockwise manner, when the core is looked down upon, and that left-handed knappers favor the reverse (Patterson and Sollberger 1986: 109). (see figure 11) This pattern of knapping is due to the muscular-skeletal structure of the hand and arm. In the non-dominant hand, the superior power of the flexors preferentially supports a rotation into the body. This motion is stronger and more controlled than the opposite. As a core is turned in a clockwise direction, the resultant cortical flakes will exhibit right-orientation. Toth saw this result in the work of modern right-handed flintknappers including his own (Toth 1985a: 611).

On the basis of these experimental results, Toth examined the lithic assemblages at two Lower Paleolithic sites: Koobi Fora, and Ambrona. The ratio of right to left-oriented flakes at Koobi Fora was 57:43 and at Ambrona it was 61:39. Toth’s experimental results show that the ratio for a modern right-handed knapper is fifty-six right-oriented flakes to forty-four left-oriented ones. Toth showed that these sets of data all show statistically significant dominance of right-oriented flakes created by right handed knappers. Toth used this conclusion to presume that there existed a dominance of
right-handed individuals at Koobi Fora and Ambrona. Toth did perform a similar
experiment and gather approximately the same data using inexperienced knappers,
though the exact details were not expressed in his article. Patterson and Sollberger
attempted to recreate this experiment using only their own flintknapping abilities, and did
not find significant results like Toth's. However, their experiment was informal and
based only on the lithics produced by the two authors, one of who is left-handed and one
of who is right-handed (Patterson and Sollberger 1986: 109-110).

**Potential for Information from the Archaeological Record**

The extent to which lithics, in light of the experiment described above or not, can
reveal information about handedness, and hence asymmetry of the brain, is not clear. It is
essentially impossible that archaeologists will find concrete, undisputable evidence for
the emergence of a population bias towards right-handedness in the archaeological
record. However, the interaction of experimental data and analysis of artifacts may
resolve the debate.

Whenever archaeology is faced with a question that is difficult to answer through
analysis of artifacts, one must constantly evaluate the strength of the evidence upon
which arguments are based. Even when the evidence appears to be enlightening, such as
if only right-handed flakes, as identified experimentally, are found at a site, one must be
aware of the possibility that the hominids responsible for this assemblage were
preferentially curating left-handed flakes. While the first assumption when faced with
this data would be that it was created by right-handed individuals only, one must consider
that perhaps the left-handed flakes were removed for use, which would imply a
dominance of left-handedness (Pobiner 1999: 91). Researchers have examined
multitudes of lithic morphological features in hopes of seeing handedness. Phillipson attempted to quantify the comfort theory, once put forth by de Mortillet, by examining the inequalities in quantity of modification of sides. Phillipson believed that the side with heaviest modification was the trailing side in use. With this criterion, the author approximated eleven percent left-handedness for Acheulean assemblage at Kariandusi, Kenya. Six of fifty-four specimens were left-handed, forty-five were right-handed, and three were indistinguishable (Phillipson 175). Work such as this, however, without experimental or ethnographic research, is without weight. Anthropologists must determine if these features truly relate to handedness and are not simply speculative.

However, the possibility is great that lithics can and will be used to explain the evolution of handedness. As Toth wrote, in 1987, “Lithic technology is probably the most complete of any proto-human behavioral system represented in the prehistoric record.” Toth continued to say that unlike fossils, lithics are resistant to taphonomic disruption and the bias that it can cause. While lithics are vulnerable when exposed to weathering and trampling, by being left unburied, for long periods of time, they are definitely the best available measure of early hominid behavior (Toth 1987: 763).

Conclusion

“It has frequently been said that there are two notable aspects of behavior that characterize hominid evolution; the first relates to speech, and the other to manual skill. In recent years, much speculation has centered around the archaeological evidence concerning both the origins of language and the beginnings of tool making, and which of these aspects of behavior may claim evolutionary precedence.” (Provins 1997: 554).

The issues presented here by Provins have been central matters of debate in archaeological theory. The origin of language, in particular, is a topic that has piqued the interest of anthropologists, linguists, psychologists, and others. The determination of the
time of language evolution in prehistory is particularly critical. Many scholars place this at the transition to the Upper Paleolithic and the emergence of anatomically modern *Homo sapiens*. Some argue that the ability for spoken language put modern humans at a large advantage over other hominids, especially the Neandertals, and accounts for the disappearance of those species and the dominance of anatomically modern humans (Le May 1972: 9). The determination of the nature of this transition, and the general course of language evolution, are not the only results that can come of an in-depth study of handedness in stone tools. Work in this area has the potential to bring together many different disciplines, most notably archaeology and physical anthropology. These two fields are inherently linked; they focus on the same large questions only through different media. Despite this, they are not often enough integrated to allow the strengths of both to help to solve an enigma of human history (Foley 1987: 380). The combination of the different methodologies and data-bases available to each field should propel the resolving of questions such as the one at hand in this paper.

Through the study of handedness, lithics have much to offer to the debate over language origins. However, archaeological evidence alone will not suffice as more than mere speculation. Instead, it must be paired with anatomical information as gathered through endocasts, evolutionary information gleaned from primatology, and observations on lithics from experimental archaeology. With the synthesis of these and other fields, lithics could provide a foundation for the understanding of language origins.
Works Cited


Figure 1 – (Le May 1972: 13) –
Areas of the brain relevant to language production, particularly the Sylvian Fissure

Figure 2 – (Hopkins, Bard, Jones, and Bales 1993: 788) – Graph demonstrating effect of posture on handedness in primates
### Table: Pooled Data on Lateral Preferences in Tool Use by Chimpanzees

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**Figure 3** – (McGrew and Marchant 1997: 118) – Table of left-hand preference in Chimpanzee tool use

**Figure 4** – (Foley 1987: 388) – The pattern of spread of *Homo erectus* out of Africa and into Eurasia

*The beginning: the expansion of Homo erectus from sub-Saharan Africa*
Figure 5 - Statistical Categories of Experimental Results

To be determined for each participant:

Mean flake length, width, thickness, volume
Maximum flake length, width, thickness, volume

Number of flakes produced

Mean flake volume/Volume of raw material

Mean # of platform scars
Mean # of dorsal scars

Length, width, thickness, and volume of tool 1

Time needed to produce tool 1

Percentage of retouch on tool 1

...(repeated for each tool)

Number of tools produced

Mean length, width, and thickness of debitage pieces

Total volume of debitage

Number of flakes per time allotted
|   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

**Figure 6 - Stabilized Table of Values (from Wednesday, July 18, 2014, 12:00 PM to 12:00 PM)**
### Figure 7 – Statistical Table of t values (Thomas p. 497)

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Figure 8 – (Olausson 97) – Graphical representation of low percentage of left-handed flintknappers in the modern population

Percentage distribution of handedness in the contemporary knapper population.

**FLAKE TYPES**

I II III IV V VI

The six flake types used in this study. Types I–III have cortical platforms (butts), types IV–VI non-cortical platforms.

Figure 9 – (Toth 1987: 772) – Illustrations of cortical flakes of different orientations

Archaeological examples of left-oriented flakes (A–C) and right-oriented flakes (D–H) from site Fyjj 50 at Koobi Fora, dated to approximately 1.5 million years ago. (Drawing by J. Ogden.)

Figure 10 – (Toth 1985a: 609) – Illustrations of cortical flakes of different orientations at Koobi Fora, Kenya
Illustration showing the sequential direction of removal of flakes from one face of a core being held in the left hand. The core is rotated in a clockwise direction due to the inherent lateral rotation of the hand. The flakes produced are right-oriented.

Figure 11 – (Toth 1985a: 609) – Demonstration of serial flaking in a right-handed flintknapper