Piaget, stone tools and the evolution of human intelligence

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Introduction

Stone tools have always played a role in archaeologists' attempts to document the evolution of human behavior. Traditionally scholars have established technological sequences whose stages are assumed to reflect the increasing cultural sophistication of the makers. Often this sophistication is tied to the intelligence of the stone knappers, as when, for example, Levallois technique is seen as requiring more 'insight' than a handaxe (Campbell 1982: 380). The weakness of such interpretations lies in their psychological naivety, for they are based on common-sense ideas, whose source is usually self-reflection, rather than rigorously established theories of intelligence.

Archaeology does have the potential to make serious contributions to the study of intelligence. Most archaeological evidence of behavior consists of patterns of objects that are the result of action, both intentional and unintentional. The results of an intentional action can give us some idea of the intelligence of the actor. The shape of a modern bridge, for example, allows us to conclude that the designer understood certain laws of mechanics. These laws required a certain organizational ability, that is, a certain intelligence. The same reasoning can be applied to the archaeological record. The pattern of megaliths at Stonehenge suggests that the designers knew certain astronomical alignments and could perhaps even predict eclipses. This tells us something about their ability to conceive relationships. Of course we do not know the specific form of their understanding (the words or symbols for example) but, if we have a workable theory of intelligence, we should be able to make some assessment of their abilities. An essential here is a workable theory of intelligence and to my mind this cannot be derived from the archaeological record or from the self-reflection of archaeologists.

The most appropriate source for such a theory is psychology, a field that is intimately involved in the concept of intelligence. Not every psychological theory of intelligence will do, however. For a theory of intelligence to be workable for the archaeologist it must be evolutionary in scope and it must deal with categories of behavior that are visible in the archaeological record. By evolutionary in scope I mean it must define intelligence in terms that are applicable to both humans and non-humans alike. A definition of intelligence designed solely to compare modern humans to one another is unlikely to encompass the behavior of apes or even pre-modern
hominids. Intelligence must be defined as a set of behaviors that varies from species to species in measurable fashion and that can change through time within a single evolving line. Many developmental theories would fulfill this requirement even though designed for human children. The theory must also be capable of assessing archaeological patterns. A theory based exclusively on sequences of action or on an actor's verbal descriptions would be useless to the archaeologist who has, with few exceptions, only patterns that are the results of behavior. The theory must define criteria that archaeologists can apply to such mundane behaviors as butchering, structure building and, most importantly, stone tools, the most abundant residue of prehistoric behavior. The theory must also be persuasive. The categories of intelligence defined by the theory need to have been confirmed again and again in many different circumstances — especially cross-culturally and interspecifically — before they can be used as a reliable yardstick by the prehistoric archaeologist.

Even with a workable theory, archaeologists are susceptible to a problem inherent in the nature of archaeological evidence — the problem of minimum necessary competence. It can hardly be doubted that many of the behaviors preserved in the archaeological record did not require the actors to use their most sophisticated intelligence. Certainly, few of our everyday behaviors severely tax our intelligence and I imagine this has always been so. When we assess intelligence on the basis of archaeological evidence, we are assessing the minimum competence necessary for that task. The prehistoric actor may have used more sophisticated abilities in realms of behavior that are archaeologically invisible. It is difficult to get around this problem. We can minimize its effect if we can increase the variety of documented behaviors for a particular time period, but there is no way logically to eliminate the possibility that prehistoric Einsteins were making crude stone tools while speculating about general relativity.

Piagetian theory

Jean Piaget has been perhaps the most influential developmental psychologist of the twentieth century. His studies of the growth of intelligence in Swiss school children became the basis of a general theory of intelligence that has since been applied in the fields of psychology, education, anthropology, and primatology, to name just a few. While his theory was based on studies of children, it was always Piaget's intention that the theory be applicable to all sequences of development; human children simply provided the most complete and observable sequence.

The theory is a stage theory. Human children pass through a sequence of stages that is invariant. The rate at which they pass through the stages varies from individual to individual, but the sequence itself is necessary; no stage can be skipped, because it is a prerequisite for the succeeding stage. The theory is also a structural theory. It conceives of intelligence as a set of principles used to organize behavior, principles that are ultimately patterns of brain activity. But these principles are not learned in a simple behaviorist sense. Rather, simple genetically determined structures are elaborated during maturation into more and more sophisticated kinds of organization (the stages). It is the action of the individual in his environment that leads to this elaboration. In other words, the individual does not passively receive new principles but must construct them himself (Piaget 1970, 1972).

Piaget's developmental scheme consists of four major stages: sensorimotor, pre-operations, concrete operations, and propositional operations. Sensori-motor intelligence is the intelligence
of pure action. Some actions such as sucking and gripping are rhythmic patterns determined by heredity and are the simplest kind of organizational principle. Soon after birth the individual coordinates such simple organizations into more complex patterns. For example, gripping and arm swinging are coordinated into a scheme of grasping and pulling objects for close examination. Sensorimotor intelligence consists only of such action schemes, some of which can be quite complex, but sensorimotor intelligence lacks any internal representation of action, that is, any conscious thought in the usual sense of the word. Such internal representation is the hallmark of the second stage — preoperational intelligence (Piaget 1972).

The internal representation of action that is characteristic of preoperational thinking results from the semiotic ability that is a prerequisite for language and this ability to ‘think’ an action gives the preoperational stage some important capabilities. One is the ability to project action into the future and to contemplate the past action. The former is necessary for even the most rudimentary planning and the latter is important if one is to monitor ongoing projects. But preoperational thinking is limited to the internal representation of sequences of action, one action after another, just as they would be acted or had been acted. Because action can only act on one quality of a thing at a time, preoperational thinking and plans can consider only one variable at a time. A famous example from Piaget’s work illustrates this limitation. When clay balls were rolled into sausages, a preoperational child assumed that the amount of clay had increased because the length had increased. She was unable to consider length and thickness simultaneously. This limitation is true in planning where, although an end result can be foreseen (because of the representational ability), only one kind of change can be made at a time. Trial and error is the only means of monitoring projects (Piaget 1972, 1974; Sinclair 1974).

Operational thinking is the stage achieved by modern adults. Perhaps the most important development of this stage is the ability to reverse and coordinate the internalized action sequences typical of the preoperational stage. Rather than thought being limited to one-way sequences of actions, operational organizations can consider an action and its inverse simultaneously (in the sense that subtraction is implicit in addition, for example). Furthermore, operational intelligence can consider several variables simultaneously and coordinate them. In the example of the clay balls cited above, a child using operational organizations can compensate for the change in one variable by considering the change in a second variable. Such relations as transitivity (A = B, B = C, therefore A = C) and classification (A + A' = B, B + B' = C) require such reversibility and coordination. Operations also permit complex planning such that ‘... instead of corrections being made after an event, that is, once the action has been carried out physically, errors are pre-corrected in virtue of the interplay of direct and inverse operations’ (Piaget 1972: 35). This pre-correction of errors is crucial in many kinds of planning, especially planning that cannot allow errors to occur before they are corrected. Space launches are an obvious example but it is even true in some kinds of stone knapping.

Operational thought actually consists of two stages, concrete operations and propositional operations. While both kinds of operations employ the same organizational principles, reversibility for example, they differ in their realms of application. Concrete operations, which are achieved earlier, organize physical entities — objects, peoples, etc. — while propositional operations organize propositions and hypothetical entities — the square root of minus one, for example. There is, however, considerable controversy about the validity of formal operations as a separate stage. It may be that they represent operational concepts applied in abstract areas of thinking rather than a true successor to concrete operations that is logically necessary (Dasen 1977).
Moreover, propositional operations would be invisible archaeologically, at least until the introduction of writing. Because of these problems, and because both concrete and propositional operations employ the same organizational principles, I will downplay the distinction in the following analysis.

The Piagetian scheme is of course far more detailed than that sketched above. It has been described for many different kinds of behavior, from math to moral development, and each of the major stages has been divided into substages. Most of these are too subtle to be reliably applied in prehistory, however, and we must be content with the coarser scheme.

Piagetian theory fulfills the basic requirements of a workable theory of intelligence that were discussed above. It is clearly evolutionary in its intent. Piaget intended that the theory be generally applicable to all sequences of development and even acknowledged that the ideal subject of study would be the psychology of fossil humans (1970). As a result, his definition of intelligence is a general one that is not specifically designed to evaluate humans. ‘Organizational ability’ is a concept that can be used to discuss the behavior of amoebas as well as the behavior of human adults. More importantly, Piaget’s categories of organizational ability, his stages, if you will, have proven useful in comparative studies. The basic sequence of stages appears to be true cross-culturally, though rates of development vary (Dasen 1977). The early stages of the sequence, at least, have been recognized in non-human developmental sequences (see Parker 1976, for example). While it would be overly optimistic to conclude from these results that Piaget’s developmental scheme is universally true in detail, it appears that Piaget has described the rough outline of a sequence of real categories of intelligence. This is just the kind of yardstick that archaeologists need.

The Piagetian yardstick can also be used to assess some of the behaviors that are visible in the archaeological record. Piaget and Inhelder (1967) have placed a great deal of emphasis on spatial concepts and many of these can be assessed on the basis of results of action. For example, only when children have achieved the stage of operational intelligence do they employ true Euclidean relationships in their drawing. In fact, the use of Euclidean concepts is one defining characteristic of operational thinking. We can recognize Euclidean relationships from the figures themselves and need not have seen the action of drawing. In addition to Euclidean concepts, Piaget’s and Inhelder’s work uses the often simpler spatial relations of topological and projective geometry. These allow assessment of the various levels of preoperational intelligence. Archaeologists have stone tools in abundance and the manufacture of these stone tools required spatial concepts, concepts that can be assessed using the methods of Piaget and Inhelder. Of course, the resolution of such assessments is not as fine as that which could be obtained if all of Piaget’s criteria were applicable. Unfortunately, many of the subdivisions within the major stages are recognized primarily on the manner in which a child achieves a particular result and this kind of sequential information is rarely available to the archaeologist.

Another advantage of Piaget’s method for the archaeologist is its reliance on qualitative criteria. We can base our assessment of spatial concepts on a few artifacts and do not require large samples. While this aspect of Piaget’s method has been criticized in psychological circles as somehow less than rigorous, it is no disadvantage for the archaeologist, whose samples are often unavoidably small and selected by the vagaries of preservation rather than by any rigorous statistical technique.

In sum, I have chosen to use Piaget for largely practical reasons. His approach to intelligence is evolutionary. His scheme of stages is broadly enough defined to be useful in cross-cultural
and interspecific studies. In fact, it has been confirmed in non-European and non-human developmental sequences. It clearly has some descriptive reality. Moreover, parts of his method can be borrowed directly to assess the geometry of stone tools. Stone tools are far and away the most abundant kind of archaeological evidence for the majority of human evolution. Evidence for other kinds of behavior is scarce or non-existent for immense spans of the paleolithic. A theory, such as Piaget's, that can squeeze a bit more understanding from these stones is therefore of great value.

**Two points in the evolution of human intelligence**

Using the Piagetian yardstick, I have been able to make a tentative assessment of the intelligence of two groups of early hominids (Wynn 1979; 1981). The earlier group is represented by artefacts from Bed I at Olduvai Gorge. These date from 1.9 to 1.7 million years ago and represent the earliest well-documented lithic technology (Leakey 1971; Hay 1976). The more recent group is represented by stone tools from the Acheulean site of Isimila, Tanzania, which date to about 300,000 years ago (Howell et al. 1972).

The spatial concepts necessary to manufacture the Oldowan tools are really rather simple. No Euclidean concepts are necessary, only topological relations. Topology is the geometry of simple spatial relations such as proximity and surrounding. Although some topological concepts do require operational thinking, the concepts necessary for Oldowan tools do not. A chopper, for example, results from striking a flake from a platform supplied by a previous flake removal. In topological terms, this requires a concept of pair; one element placed immediately next to one preceding element (Fig. 1). The position of only one preceding element, in this case a flake removal, needs to be taken into account. This is true even if many flakes are eventually removed. The paired nature of chopper knapping yields an irregular edge with no intentional overall morphology, a characteristic of many Oldowan artefacts. The geometry of a scraper is a bit more complex (Fig. 2). Several flake removals must be placed in such a way that the result is a continuous sequence. To do this it is necessary to consider the position of not just the preceding flake removal but also ones that have gone before. The relevant topological concept is that of order. Both the pair and sequential order can be achieved by a process of trial and error, that is,
one flake is struck off, the result checked and then another struck off until an acceptable tool has been made. The Oldowan knappers need not have had a relatively complete plan of action and need not have employed operational thinking. Their 'minimum necessary competence,' to which reference was made earlier, was preoperational intelligence. There is nothing in the archaeological record for the Oldowan that clearly argues for a more complex intelligence. All of the subsistence activities and social behavior for which we have reliable evidence are well within the power of preoperational organizations. The 'stone circle' at the DK site (Leakey 1971), the possibility of cooperative hunting, the carrying of raw material from factory sites to home bases, can all be accomplished with the representational thinking and trial and error planning of preoperational intelligence. Modern chimpanzees regularly perform comparable tasks and they do not employ operational concepts (Parker and Gibson 1979). I see no reason to assume that the hominids at Olduvai Gorge one and three quarter million years ago were remarkably intelligent just because they are likely to have been our ancestors.

The Acheulean artefacts from Isimila, on the other hand, were clearly manufactured according to operational concepts. The most revealing of the artefacts is the handaxe, a tool whose shape requires some rather sophisticated Euclidean and projective relationships (Fig. 3). Most obvious is the symmetry. Piaget has argued that symmetry is never passively perceived (true symmetry is extremely rare in nature) but must be actively constructed by means of the operational relation of reversibility. Put simply, bilateral symmetry results from the reversal of a shape across an imaginary midline. The ability to perform such a task is not achieved until the operational stage because it requires the simultaneous conception of the shape and its inverse. Since the stone cannot be folded to provide a model for trial and error flaking, the inverse must be constructed in thought, and inversion in thought is, as we have seen, a characteristic of operational thinking (Piaget and Inhelder 1967; Wynn 1979). For very early handaxes (about 1.5 million years old) it is possible that archaeologists have been optimistic in seeing symmetry that was not conceived by the maker. I think it is clear, however, that this Isimila handaxe reflects an idea of bilateral symmetry that the artisan took some care to achieve.
More telling than the bilateral symmetry is the symmetry in cross-section. If the handaxe were cut through at any angle the resulting cross-section would be approximately symmetrical. Most of such cross-sections could not have been directly perceived by the knapper because he
could not 'see through’ the surface of the artefact. The knapper must have constantly imagined the simultaneous effect his actions would have on a virtual infinity of cross-sections. Such a result is beyond the abilities of trial and error and requires the complex substitutions and compensations of operational intelligence. Fig. 4 presents a handaxe with bilateral symmetry that was achieved by a minimal amount of trimming. Furthermore, the trimming is not contiguous but is concentrated in four distinct regions. The knapper must have had an intended result and, more importantly, a plan for achieving that result with a minimum of actual flaking. This may seem a simple task but it is not. The knapper had to have conceived of the shape as resulting from an arrangement of parts (potential trimming) and to choose those parts that were essential. Pre-correction of errors was necessary in order to choose which trimming was essential and which superfluous. Trial and error trimming can achieve an imagined shape only by trimming and checking, trimming and checking until the imagined shape is approximated, usually by contiguous flaking and rarely through a minimum amount of work. In sum, the shapes of later Acheulean handaxes and the means for achieving these shapes required the organizational abilities of operational intelligence. As we have seen operational intelligence is typical of modern adults.

Later Acheulean handaxes are separated from Oldowan choppers by almost one and a half
million years of human evolution. At some point in this span humans achieved operational intelligence. The archaeological record, as it currently stands, gives us little idea as to precisely when. Early in this span there was a cultural/technological development represented by the appearance of industries which included handaxes — the Lower Acheulean and the Developed Oldowan B. While these artefacts fulfill a typological definition of handaxe they are not equivalent to the later Acheulean artefacts in terms of the necessary geometric concepts. They lack the fine cross-sections of the later handaxes and also the minimal trimming patterns that argue for an operational concept of whole and parts. Unlike the earlier Oldowan artefacts, however, they do present an overall shape and this shape occasionally approaches bilateral symmetry (Fig. 5).

Figure 5 Early handaxe from Olduvai Gorge, tending towards bilateral symmetry but thick and crudely made.

Herein lies a problem of interpretation. As we have seen, true symmetry requires operational concepts. Must we then conclude that Lower Acheulean and Developed Oldowan stone knappers employed operational concepts as early as 1.5 million years ago? Such a conclusion stretches credulity, especially since the contemporary fossil hominid was an early form of *Homo erectus*. My inclination is to downplay the symmetry of early handaxes. I have two reasons for this skepticism. First, many of these early handaxes are only roughly symmetrical — none approaches the fine symmetry of later examples — and for these the symmetry undoubtedly lies in the mind of the archaeologist rather than the mind of the stone knapper. Second, it is possible that a form resembling symmetry could be copied from models in nature (leaves, for example) using trial and error plans. Such copies would not require a concept of symmetry. I think it is especially telling that these early handaxes lack symmetrical cross-sections and minimal trimming patterns, because these do require a concept of symmetry and the precorrective plans to achieve it. In sum, a weak case can be made for operational thinking as early as the Lower Acheulean, but the case is too weak to be persuasive. Interestingly, both Lower Acheulean and Developed Oldowan B
handaxes required the same geometric concepts and it therefore seems unlikely that a separate hominid species was responsible for each.

The appearance of handaxe industries is not the only technological development that carries few or no implications in a Piagetian analysis. Levallois and blade techniques are further examples. Levallois technique is often cited (e.g., Campbell 1982) as requiring a sophisticated intelligence to ‘see’ the flake in the core. From a Piagetian perspective, however, it is no more complex than a later handaxe. It requires an idea of end result (but so does a chopper) and a plan of action in which the relation of whole to parts must be carefully considered. Such planning requires operational pre-correction of errors. But Levallois technique lacks the complex projective geometry necessary for fine symmetrical cross-sections. Handaxes are therefore more informative than Levallois technique when it comes to assessing intelligence. Levallois is a difficult technique to master, which probably accounts for the respect accorded it by archaeologists, but it is not very difficult conceptually. The same is true for the manufacture of prismatic blades; the technique requires a careful relation between whole and parts (core and blades) and this requires pre-correction of errors. Beyond this it is not a difficult technique conceptually and certainly does not represent a level of intelligence greater than that necessary for later Acheulean handaxes. I do not wish to belittle the importance of the Levallois and blade techniques as technological developments in human prehistory. I simply wish to point out that their appearance does not necessarily mark a leap in intelligence.

The Piagetian sequence I have described has important implications for our understanding of human evolution. If Oldowan hominids had pre-operational intelligence, and nothing in the archaeological record suggests otherwise, then they were little more intelligent than modern apes. Yet the basic distinguishing hominid morphology of bipedalism had appeared by at least 3.5 million (Johanson and White 1979). This would imply that the process of hominid evolution prior to 1.5 million (the approximate end of the Oldowan) had little to do with increasing intelligence. It was between 1.5 million and 300,000 that modern intelligence evolved. Indeed, the geometry of later Acheulean handaxes requires a stage of intelligence that is typical of fully modern adults. No subsequent developments in stone tool technology require a more sophisticated intelligence. This certainly argues against a commonly held notion that morphologically modern humans were more intelligent than the archaic forms of *Homo sapiens*, such as the Neandertals, who preceded them.

It is possible that the enigmatic stage of ‘propositional’ operations was achieved after 300,000 but, as its importance is controversial and as it would be invisible archaeologically, this must remain a moot point.

Conclusion

The use of Piagetian theory has permitted a rigorous assessment of the intelligence of two hominid groups. The theory supplied a set of specific criteria that could be used to analyse stone tools, criteria that were established by careful psychological research. Because the analysis was based on such a sound psychological method, I believe it is far more reliable than the common sense interpretations usually employed by archaeologists. The resulting sequence is not elaborate — only two groups could be assessed reliably — but it is a ‘real’ sequence. Piagetian analysis is not without its limitations, however. When only geometric criteria can be used, as is
the case with stone tools, the resolution of the analysis is not very fine and we are limited to applying Piaget's coarse major stages. As a result the analysis misses subtler differences in intelligence. It seems likely, for example, that Lower Acheulean stone knappers were more intelligent than Oldowan stone knappers but the Piagetian analysis does not distinguish them adequately. Perhaps some other psychological theory will ultimately prove more informative in archaeological analysis. It is necessary, however, that archaeologists turn to well established theories if they wish to make serious contributions to an understanding of the evolution of intelligence.

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References


Abstract

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Archaeology can be used to study the evolution of human intelligence but to do so archaeologists must employ well established theories of intelligence. Piagetian theory is especially useful because it is evolutionary in scope and, just as important, can be used to analyze stone tools, the most abundant residue of prehistoric behavior. Using Piagetian method to analyze artefact geometries, the author has been able to assess the intelligence of two groups of early hominids. Oldowan tools required very simple spatial concepts, indicating an intelligence not much greater than that of modern apes. This suggests that human evolution prior to 1.5 million years ago may not have involved selection for intelligence. Later Acheulean artefacts, on the other hand, required sophisticated spatial concepts, indicating that an essentially modern intelligence had evolved by 300,000 years ago.

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