Seen and not heard?

Evaluating the prevalence of imitation versus guided learning as methods of acquiring skill in the Paleolithic

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ABSTRACT

Learning is an integral part of the human experience, one which can take a wide variety of forms depending on the context. The two broad categories of cultural learning are observation/imitation learning and directed learning, also known as scaffolding. Which type of learning a culture employs most often depends on the culture's values and on the skill being transmitted. The archaeology of learning focuses primarily on craft learning, or the transmission of technical and cultural knowledge required to effectively make physical objects. This paper examines these two categories of learning and applies them to the archaeological record in order to determine whether the record can reveal methods of learning. I conclude that an observation/imitation model of learning does not suffice for the transmission of technologies more sophisticated than Acheulean. Therefore, directed learning predates the appearance of *Homo sapiens* and may represent a critical moment of cognitive development.

INTRODUCTION

For centuries, thinkers and philosophers maintained that only humans could make and use tools. Though we now know that such statements are far from true, no nonhuman group has been found whose tool making capacities can rival the variety and sophistication of all but the most rudimentary human tool traditions. *Homo sapiens*' unique intelligence, sociability, and capacity for fine motor control has allowed our species to create objects of breathtaking beauty and complexity for hundreds of thousands of years. A small fraction of these ancient tools have been preserved, allowing modern archaeologists the chance to speak concretely about the techniques and technical capacities available to Paleolithic humans. The prehistoric record of stone tools, the most abundant form of archaeological data in the Paleolithic, spans millions of years, extending from crude handaxes that can be hard to distinguish from naturally broken rocks to breathtakingly beautifully crafted blades or statuettes that could only have been created by artisans with years of experience.

No matter the sophistication of the tools, the question of how they were made often dominates the conversation. Detailed technical analyses and experiments in replication have created a sequence of events – commonly in archaeological science called a *chaîne opératoire* (Leroi-Gourhan 1964; Soressi & Geneste 2011) – required to knap each type of tool, revealing in the process that some techniques can be learned easily and others necessitate extensive training and practice. Many archaeologists are content to let it go at that, choosing instead to focus on the purpose of each tool or the symbolism behind tool shape or material. Only a handful of studies (e.g. Pigeot 1990; Grimm 2000; Fischer 1989; Hill & Gunn 1977) have been done attempting to determine how exactly the complex skills required to make stone tools were passed between individuals in prehistory. For the most part, the lack of attention to this aspect of tool production is related to the difficulty of pinning down individuals within the archaeological record. Prehistoric craftsmen did not sign their work, and the archaeological record is nowhere near detailed enough to allow single individuals to be tracked across time and space. Certain craftsmen have been singled out due to a particular physical flaw – the cave of Chauvet in France, for instance, contains a series of handprints made by a single individual with a crooked little finger (Herzog 2012) – but such instances are rare and each individual is generally only distinguishable at a single site. More commonly discussions of artifacts are forced to leave out individuals when examining stylistic or technical aspects of the artifacts in question.

Moreover, dating artifacts remains an approximate science. Even the best radiometric dates cannot be exact down to the precise year, and with increased age comes increased uncertainty. Paleolithic artifacts have been traditionally dated to within one hundred years, a practice that works splendidly for establishing chronology but makes discussing individual generations extremely difficult (Klein 2009). Thus archaeological work concerned with the passing down of skills or knowledge across individuals or even across generations is by necessity difficult and any results gathered are far from certain. However, merely because work is difficult does not make it impossible. Certain strategies have been suggested for identifying individuals within the Paleolithic record (see Pigeot 1991 for an overview). In particular, archaeologists look at skill and style in order to pick out individuals within the larger record. Looking at style allows archaeologists to make distinctions between and within groups. While style is an extremely valuable angle through which to view the record, it can be difficult to interpret at times and does not necessarily provide information about the wider structure of a society. This paper is primarily concerned with studying the individual in relation to society, so I will not focus significantly on style as a way to detect individual craftsmen. See Hill & Gunn (1977) for further discussion of this angle. Studies of skill, by contrast, provide a way of examining individuals in relation to their wider societies (Eren et. al. 2011). Using analyses of skill, archaeologists can learn about not only the artifacts themselves but also about a culture's social hierarchies and organization (Bamforth & Finlay 2008). By necessity, identifying the skill used to make a certain artifact forces the archaeologist to consider the individual craftsman and the ways that individual interacts with their environment and their fellow craftsmen. Skill, unlike style, is nearly always relative, with individuals being considered more or less skilled than their peers rather than existing in a vacuum.

This paper will focus on one angle of the study of skill, namely the study of learning and information transfer. No individual is born with the skills needed to create perfect tools, and no complicated tradition can be recreated from nothing by any craftsmen of ordinary native ability.

Therefore, novice craftsmen must have learned their craft in some fashion. Ethnographic research on learning has shown that craft learning primarily happens either through observation/imitation or through direct instruction (Ferguson 2008; Lave 1982; Paradise & Rogoff 2009; Poirier & Hussey 1982; Shipton 2010). Observation/imitation learning means that the novice gains knowledge by observing the actions of experts and imitating their behavior, either on their own or in the vicinity of the expert. For the most part little direct contact occurs between the novice and the expert in this model, and the novice finds mistakes in their process by seeing that their end product does not match that being created by the expert rather than by having those mistakes pointed out and corrected by an instructor. By contrast directed learning requires experts to take a far more active role in the learning process, either by offering verbal instruction to a novice or by physically helping them in some fashion. In some cases directed learning takes the form of collaborative processes between novices and experts wherein the expert allows the novice to help them create an artifact or, alternatively, performs difficult tasks in the creation of a novice's artifact.

In this paper I will examine prehistoric tool making sites in an attempt to determine how knowledge of how to make stone tools was transmitted across individuals. Though it may not be possible to come to any firm conclusions using only the evidence available, I believe that enough archaeological data exists to offer some hypotheses. I will focus primarily on the European Paleolithic record, examining first general trends and observations recorded by archaeologists about Middle and Upper Paleolithic technologies, and then presenting two case studies of French Upper Paleolithic sites with clear evidence for skill variance. The Middle Paleolithic period in Europe spans from approximately 300kya to 30kya, ending when the appearance of undeniable symbolic thinking in Europe marks the transition into the Upper Paleolithic. This period is generally understood to last until approximately 10kya, or until the advent of agriculture in the Near East (Klein 2009). Upper Paleolithic technological traditions are, as a rule, comprised of elaborate, often composite tools which require significant amounts of skill to create properly. Different cultures within this period have clear stylistic variation, likely as a result of differing traditions and symbolic conventions (Foley & Lahr 2003). Because of this formal variation, and due to a rich archaeological record, the Upper Paleolithic period lends itself to studies of skill and variation across cultures.

This paper will begin with a short exploration of the concept of culture, in order to clarify how the term will be used in this research. Though it is something of a digression to include this discussion, I believe it is important to clearly define the term, as tool making is an inherently cultural process and the concept of culture is often understood differently by each person who uses it. I will then look at learning among nonhuman apes in order to establish a baseline for learning behaviors. The following section will briefly examine ethnographic work on craft learning and will provide a more detailed model of how to determine learning patterns through the archaeological record. Finally, I will turn to the Paleolithic itself and, focusing on certain well documented archaeological sites, will try to establish how information was transferred between individuals at that site.

CULTURE

The earliest explicit definition of culture by an anthropologist was in 1871 by E.B. Tylor. He offered a comprehensive definition of the term, stating that culture was, “that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society” (Tylor 1871). This definition proved highly influential, shaping not only how ethnographers approached the study of cultures but how researchers in anthropology and other disciplines conceptualized culture as an abstract (Kroeber & Kluckhohn 1952). However, due to the complexities inherent in the term – as well as the various political agendas that inevitably sneak into scholarship – Tylor's definition was rapidly joined by others, many of which contradicted, ignored, refined, and otherwise treated his as one of many possible definitions rather than the last word on the subject. Most scholars agree broadly with Tylor's definition but quibble with the details, tweaking each individual component to suit their individual academic and political needs. Indeed, so many anthropologists have attempted to refine the concept that when Kroeber and Kluckhohn, working in the 1950s, attempted to collect all existing definitions they generated a list of over one hundred and fifty different definitions and the discipline has not since stopped producing other. Geertz offers, "man is an animal suspended in webs of significance he himself has spun [and] I take culture to be those webs" (1973:2) while Shweder suggests, "community-specific ideas about what is true, good, beautiful, and efficient" (Borofsky et. al. 2001:437). One introductory text, using a definition nearly as broad as Tylor's original, presents culture as, "the totality of learned, socially transmitted customs, knowledge, material objects, and behavior" (Schaefer 2011:81). Taking another tactic, Borofsky suggests not even attempting to define the term but rather turning it into a discipline-wide code word, to be used by anthropologists from different theoretical traditions to find common ground (2001).

Inherent in the definitions presented by cultural anthropologists is the notion that culture is a subjective quality, a feature of human existence which must be teased out through careful ethnographic and theoretical work. This presents a problem for archaeologists, particularly archaeologists of non-literate societies, who do not have the luxury of using interviews or participant observation in their research. Attempts to address this limitation traditionally have taken one of two forms: either a call to disregard culture and human agency entirely or an attempt to redefine culture yet again so as to create a usable definition. The first approach gave rise to processual archaeology, a theoretical school which placed no importance whatsoever on issues of human agency in favor of examining material and environmental causes for change over time. Proponents of this school defined culture as "humanity's extrasomatic means of adaptation to the environment" (Trigger 1990:553) and opted not to give it much significance in their interpretations. In their efforts to make archaeology more scientific they turned to distribution patterns and adopted theories of rational choice to explain cultural variation. Similar assemblages were assumed to come from cultures proximate to each other and human actors believed to react to external stimuli only in ways that would maximize the overall well being of their culture (Hodder 1985; Cowgill 1993).

Critics of such an approach, loosely lumped together as post-processual archaeologists, choose a different approach to the problem. Instead of dismissing culture altogether, they try to craft of culture definitions that sidestep the need for direct interviews. Trigger offers "the capacity to manipulate symbols" (1990:555) while Noble and Davidson simply conflate culture with the ability to use language, defined by them as "the symbolic use of communicative signs" (1991:224). These definitions are reminiscent of those used by scholars of non-human culture, who are as limited as archaeologists when it comes to interviewing their subjects. McGrew, in a survey of culture in nonhuman primates, offers the following guidelines: "Culture is considered to be group-specific behavior that is acquired, at least in part, from social influences. […] Prima facie evidence of culture comes from within-species but across-group variation in behavior" (1998:305). Perry, in a similar study, defines culture as "behavioral variation that owes its existence at least in part to social learning processes, social learning being defined as changes in behavior that result from attending to the behavior or behavioral products of another individual" (2006:172).

Examining culture from a nonhuman perspective is valuable in studies of Paleolithic humans because it requires scientists to confront their preexisting assumptions. While the reality of Paleolithic cultures, unlike nonhuman cultures, cannot be denied, approaching their study from a place of ambiguity cuts down on the assumptions that might otherwise be made. Because so little concrete evidence exists, applying humanist models of culture to Paleolithic cultures puts scientists in danger of transposing modern biases or stereotypes onto the cultures in question. These practices can lead to unfounded but widely accepted assertions about past cultures, such as the notion of European Paleolithic parietal art being an indication of shamanist practices by ancient peoples. Proponents of this view base many of their interpretations on studies of extant hunter-gatherer cultures such as the San in South Africa (see Lewis-Williams 1995; 1997), an approach which both assumes that the extant cultures have been unchanged since prehistoric times and that shamanist practices can be generalized across continents. While certainly ethnographic research can help in the study of prehistoric cultures, drawing specific and detailed parallels presents untestable hypotheses and may even lead to scientists to overlook evidence from the ancient cultures in question. Approaching those cultures with a nonhuman culture model in mind is not a perfect solution, by any means, but ethologists studying nonhuman groups often begin their research by asking *whether* the group displays certain characteristics as opposed to jumping to examining *how* those characteristics are displayed. Due to the temporal distance between modern scientists and upper Paleolithic peoples this more cautious approach seems more scientifically sound and less open to unconscious biases.

In this paper, therefore, I have chosen to define culture broadly, highlighting the learned and group-specific components without making it subjective enough to require confirmation though ethnographic research. Thus I have defined culture as *the learned ability to manipulate group-specific symbols*. This definition allows for inter-cultural variation, as highlighted by McGrew, while preserving the emphasis on symbolic and abstract thinking so integral to human consciousness. Symbols, in this case, are defined as objects or concepts which have been given meaning. This meaning can be either arbitrary, such as the meaning assigned to the letters of the alphabet, or drawn from some more practical property, such as the use of a certain tool for a particular task. Whichever form they take, symbols must be learned, thereby reinforcing the non-instinctive nature of culture.

Emphasizing the learned and symbolic nature of culture allows for lines to be drawn between cultural and instinctive transmission of knowledge. Though apparent teaching and learning behaviors can be seen among animals as diverse as primates, raptors, felines, and cetaceans (Caro & Hauser 1992), not all of those behaviors can be definitively classed as cultural rather than instinctive. Evidence of variation in behavior or instruction method across groups provides stronger evidence for cultural rather than instinctive transmission of knowledge and information. Using these criteria, tool making behaviors in the Paleolithic can be firmly classified as cultural, particularly as tool forms and creation techniques begin to vary across groups. Though it comes as no great revelation that prehistoric humans possessed culture, establishing the evidence for that culture allows for a stronger foundation upon which to build further arguments about how variations between cultures may have affected tool making and craft learning among individuals.

NONHUMAN PRIMATES

The notion of cultural learning in nonhuman primates is no longer a revolutionary one. Several decades of observation and experimentation have proven without a doubt that learned skills play an integral role in the lives of most primates and that the capacity to learn those skills has been selected for over the course of their evolutionary histories (see Poirier & Hussey 1982). In this capacity *H. sapiens* is no different from its close cousins: learned behavior is integral to nearly all social species, particularly those with more generalist trends (e. g. Poirier & Hussey 1982; Greggor 2012; Fouts 1997). However, human societies nearly always use a mixture of observation/imitation and guided learning in order to transmit knowledge and customs across generations (Tehrani & Riede 2008; Crown 2001). The form of learning is tied to cultural values rather than the physical or cognitive capacity of the individuals involved. Among nonhuman primates, by contrast, the primary mechanism of information transfer is observation/imitation for nearly all behaviors. Juvenile primates learn by observing their mothers and elder siblings (Poirier & Hussey 1982), while among adults behaviors are primarily transferred through observation of conspecifics (Whiten et. al. 2005; Whiten et. al. 2007). Instances of guided learning in the wild do exist, but they are far less common than purely observational learning (Poirier & Hussey 1982), while the presence of formal teaching in nonhuman primates depends in large part on the strictness of the definition of teaching (Caro & Hauser 1992).

Social primates in the wild rely on a complex system of social traditions and hierarchies to survive. It is vital that infants and juveniles learn to navigate their social group as quickly as possible, particularly for species with strict hierarchies. Because group dynamics vary between groups, sometimes dramatically, juvenile primates are not born with an instinctive knowledge of how to navigate their world, but rather with an instinctive capacity and desire to absorb and process information. Infant chimpanzees, for instance, spend their first several months first held by and later clinging to their mothers and observing (Plooij 1984). From this position they are able to watch their mothers interact with other adults and perform daily tasks, thus introducing them to the complex set of behaviors they will need to learn to reproduce. As infants age and begin to leave their mothers for brief periods of time they start developing useful skills through play and exploration (Plooij 1984). Occasionally chimpanzee mothers or other adults will deliberately teach their infants certain skills, usually by demonstrating the task slowly and carefully for the infant to observe. Fouts (1997) recounts an incident in which a young female was having difficulties in manipulating a nut-cracking tool. After several failed attempts, her mother took the tool from her and, motions deliberately exaggerated to show precise details of grip and angle, showed the female the proper method of nut-cracking. When the female took the tool up again she was able to imitate her mother's technique and her results improved dramatically. Boesch (1991) reports similar observations, as well as a range of other instructive behaviors such as mothers providing their children with high quality nut-cracking tools and positioning nuts appropriately on anvils before the juveniles attempted to crack them. Deliberate teaching of this sort appears to be confined to either transmitting complex skill sets such as tool use or to specific cultural norms such as commonly eaten foods, though the latter instances are less well documented (Boesch 1991; Bard 1994; Falk 2004).

Chimpanzees raised in captivity not only display a wider range of behaviors than do individuals raised in the wild but also engage in more deliberate teaching and guided learning. In his work with captive chimpanzees Fouts (1997) showed that not only are individuals capable of learning through deliberate teaching, they are also capable of spontaneously using those methods to teach others. His work highlights the adaptive capacities of chimpanzees: animals exposed to formal teaching methods are capable of understanding the purpose and mechanism of teaching and turning that understanding into action. In particular, Fouts used a technique known as molding to teach several chimpanzees American Sign Language. Molding involves taking an indivdual's hand and shaping it into the desired sign, thus giving the individual a more in depth knowledge of the sign than they would have had through simple observation. The technique helped his first subject – a female named Washoe – master difficult signs, and she in turn was later seen employing molding to teach her young child when he had difficulties learning particular signs.

The use of molding between chimpanzees demonstrates a high level of sophisticated cognition and behavioral flexibility. Chimpanzees in the wild are rarely faced with challenges that cannot be solved through more traditional methods of casual observation and the occasional demonstration from an adult or conspecific. Like human children, juvenile chimpanzees typically develop social and communicative skills through immersion and absorption at a young age (Fouts 1997; Plooij 1984). Human-reared chimpanzees who are taught advanced skills such as complex tool creation or American Sign Language are faced with a challenge unlike something any a chimpanzee would encounter in the wild, akin to a human being taught a foreign language, and require a different approach. By switching from more passive demonstration to direct instruction through molding, Washoe demonstrated an understanding of the specifics of the situation. She was able to remember a technique used on her as a juvenile and adapt it to the situation at hand, employing the same technique to teach a different sign, thereby ruling out pure imitation as an explanation for her behavior (Fouts 1997).

Teaching behavior demonstrates not only social sophistication but an at least rudimentary theory of mind, or awareness of the perceptions, feelings, and information available to others. In laboratory situations chimpanzees have been shown to have an excellent grasp on the concept that a conspecific in a different location does not have access to the same visual information they do and are able to use this understanding to inform their behavior (Hare 2011). Theory of mind also influences teaching behaviors – without a well developed theory of mind individuals cannot realize that others do not possess the same mastery of a task as they do and thus cannot offer deliberate assistance. Observational learning does not require as deep a grasp on the psychology of other individuals, but teaching behaviors in both wild and captive chimpanzee populations are common enough to be more than statistical aberrations, thus suggesting that the common reliance on observational learning stems from practicality and effectiveness than from any deficit in cognition.

Studying chimpanzees allows researchers to establish a cognitive and behavioral baseline. Certainly even the early hominids were not direct behavioral analogs to modern chimpanzees, much less prehistoric *H. sapiens*, but neither were any prehistoric human populations directly analogous to modern humans. Cognitively Paleolithic *H. sapiens* were nearly identical to modern humans, but cognition does not have a one to one relationship with behavior, especially when dealing with socially learned behaviors. The methods employed by chimpanzees to transmit those behaviors allow us to make some assumptions about the basic methods used by Paleolithic humans to teach both rudimentary and complex skills. For instance, it seems likely that, like both chimpanzees and modern humans, prehistoric populations learned language and basic social navigation skills through observations and immersion, with some help from adults if they stumbled. Human mothers seem more likely than chimpanzee mothers to deliberately demonstrate skills (Bard 1994), but the skills required of a human child – such as the acquisition of language – are more complex than those required of a juvenile chimpanzee. It seems likely that deliberate teaching as the preferred method of knowledge and culture transmission increased alongside the complexity of the skills being transferred. Thus Paleolithic human cultures likely employed at least some methods of deliberate teaching when transferring knowledge, particularly to their children.

Primate archaeology

Because of the rarity of deliberate teaching behaviors among nonhuman primates, and because even common behaviors do not often preserve well in the archaeological record, identifying archaeological evidence of learning among nonhuman primates presents a daunting challenge. Studies of ancient hominid cognitive and social capacities use lithic artifacts almost exclusively, but no nonhuman primate has ever been found to create lithic artifacts without prompting and demonstrations from human researchers. A few apes, however, have been taught to manufacture stone tools, thus producing an archaeological record, albeit a recent one. Due to the controlled conditions of these experiments, paleoarchaeologists have the opportunity to examine both the artifacts created and the process used to create them, a chance not often afforded to those who study prehistoric peoples.

A long-term study of nonhuman lithic capabilities debuted in the 1990s (Toth et. al. 1993; Schick et. al. 1999). Kanzi, a captive bonobo known for his communication skills, was given the chance to observe humans creating stone tools and shown the value of the sharp flakes they produced. Over the course of several months Kanzi learned not only to make use of sharp flakes to cut through rope or cloth but to produce his own, using first a percussion technique modeled to him by a human knapper and later a throwing technique of his own invention. His human instructors did not offer any assistance or deliberate teaching, merely allowed him to observe them at work and gave him access to raw materials and rewarded experimentation on his part with verbal praise and encouragement (Toth et. al. 1993). Over the course of several years Kanzi acquired proficiency at stone tool creation. Equally strikingly, Kanzi's sister and her children have also begun to acquire the necessary skills through careful observation of Kanzi and of human toolmakers (Whiten et. al. 2009).

The tools produced by Kanzi and his kin have been examined in comparison to Oldowan style stone tools, which they most closely resemble. Whiten et. al. (2009) compared bonobo-created tools to both ancient and modern human-created tools and found that the bonobo-created tools were of systematically lower quality than either set of human-created tools. Both modern and ancient human toolmakers deliberately sought out certain angles and surfaces for impact, choosing surfaces with more acute angles, unlike the bonobo toolmakers, and the flakes created by humans were both larger and originated from a higher proportion of the original stone than did those created by Kanzi and his kin (Whiten et. al. 2009). When examined side by side the tools made by humans and the tools made by bonobos are clearly differentiable by experts. The reasons for these discrepancies in quality are as yet undetermined, with both cognitive and biomechanical explanations being considered by the researchers. The method used by the bonobos to learn tool making, however, has not been considered an important factor. Modern human toolmakers typically learn the craft through intensive instruction, often in one to one master-apprentice type relationships (Ferguson 2008). This method allows for a shorter learning curve, leading to some individuals gaining proficiency with basic techniques within a few weeks, as opposed to the several months required by Kanzi (Sheets 2013; personal observation). It has been demonstrated that both wild and captive chimpanzees use techniques other than pure observation to learn complex skills such as tool use, and that individuals who are taught skills rather than simply allowed to observe others using them pick up those skills more quickly and with greater proficiency. Unlike chimpanzees, wild bonobos are not habitual tool users, thus making it difficult to draw similar distinctions between observational and guided techniques of learning, but the cognitive capacities of the two subspecies have been shown to be similar enough for a cross-comparison to be meaningful.

Because few experiments have been run on ape tool creation, there is only a small pool of archaeological evidence to use in comparative studies. The studies which have been undertaken have produced valuable but inconclusive results about the difference in quality between ape-created tools and human-created ones. Though these discrepancies could be due to biomechanical differences between apes and humans, the extended trial and error period required by Kanzi to acquire proficiency in tool creation seems to be influenced in large part by the methods used to teach him. Both ethological and experimental studies on chimpanzees have shown that adult individuals regularly use more direct methods of instruction when transmitting complex skills such as tool use, and it seems likely that ancient hominids employed similar techniques. Thus the difference in quality between the bonobo-created tools and the human-created ones may potentially be attributable to a difference in skill transmission as well as cognitive or biomechanical differences. Unfortunately the data to test this hypothesis do not currently exist, as no studies have attempted to teach apes to knap stone through more direct methods.

ETHNOARCHAEOLOGY

Common anthropological wisdom holds that children acquire craft skills in the same way they do other cultural practices, namely through observation and absorption at a young age (Flenniken 1984). In many cases, ethnographic data seems to support this assumption, particularly when the line is drawn between 'formal' and 'informal' learning. These two terms do not exactly map onto 'observational' and 'directed' learning as I have defined them here. 'Formal' learning, in ethnographic literature, corresponds to learning that happens in a school-like setting through direct teaching, while 'informal' learning refers to learning that happens within the community as a part of the learner's daily activities (Lave 1982). Decades of ethnographic research have provided a rich array of data about learning, much of which does seem to take place in informal context (see Paradise & Rogoff 2009 for an overview). The strict distinctions between formal and informal learning, however, are often artificial categories, created by anthropologists rather than the communities being studied, and these strict boundaries can obscure actual behaviors being observed. In particular, focusing on the formal/informal dichotomy understresses the distinction between theoretical and practical knowledge acquisition. Though both types are required for the successful acquisition of skills, they are often lumped together and studied as a single process (Read 2006; Wallaert-Pêtre 2001). Learning through observation and imitation, as favored by anthropologists as the primary method of skill acquisition, easily allows for the transfer of theoretical knowledge, such as the required *chaîne opératoire* needed to create objects, but does not always correspond with a similar transfer of practical expertise. Read (2006) points out that understanding how to undertake a certain task does not necessarily mean that an individual will physically be able to reproduce it, much less reproduce it accurately.

In examining the ethnographic literature on craft learning with an eye to how the preferred method of knowledge transmission corresponds to levels of practical and theoretical knowledge in learners, a rough correlation can be drawn between cultures in which learning is done primarily through observation and imitation and cultures in which trial and error is a large factor in developing practical craft knowledge. Lave (1982) describes how apprentice tailors in Liberia, who gain expertise in their craft primarily by watching master craftsmen and older apprentices work, usually must attempt each new type of garment dozens of times before finally mastering them. Similarly many of the instances of observational learning described by Paradise and Rogoff (2009) involve learners gaining practical knowledge through repeated attempts at reproducing the products made by individuals around them. By contrast adze makers in the Highlands of New Guinea offer significant direct instruction to apprentices, including both verbal and gestural advice, as well as the chance to participate directly in technically difficult parts of the knapping process before the apprentices gain the skills to undertake the entire process alone (Stout 2005). This scaffolding process leads to apprentice products that, while recognizably created by non-masters, do not come about through a process of trial and error. Gowlland (2012) described how modern Chinese potters in the town of Dingshu physically direct their apprentices' movements in the early stages of learning each step in the *chaîne opératoire*, again leading to novice creations displaying a lack of skill rather incomplete knowledge. Equally importantly, more scaffolding-heavy learning processes result in more strictly conventional end products. Novice craftsmen in these structures are guided through a defined set of steps to produce a certain product which strongly resembles non-novice products in all but skill level (Crown 2001).

The favored methods of instruction vary not only by culture but also according to the materials being used in craft production. Clay, for instance, can be shaped and reshaped innumerable times before firing, thus lending itself to a trial and error method of learning (Ferguson 2008). Pre-cut cloth can be sewn and then taken apart again without significant difficulty, as demonstrated by the Liberian apprentice tailors, who may resew a garment several times before producing an acceptable one (Lave 1982). By contrast material such as stone cannot be reused, and evidence of scaffolding is much more common in studies of stoneworking (Ferguson 2008; Stout 2005). Higher instances of scaffolding or restrictions on independent experimentation also appear to correlate with scarcity and value of raw materials, with the clearest evidence of novice experimentation being strongly associated with widely available and low quality materials (Ferguson 2008).

As always when dealing with matters of human behavior and cultural tradition, different methods of instruction fall on a spectrum. No culture uses exclusively one instructional method or the other, though certainly some fall further towards either extreme than others. Gamble (2010) describes the training of South African cabinet makers, which is primarily observational in nature but involves masters stepping in to correct certain errors. The Chinese potters studied by Gowlland (2012) allow their apprentices time to observe techniques without direct instruction on how to recreate them. Pueblo potters very rarely engage in direct instruction, but will occasionally correct or advise novice potters imitating their techniques (Crown 2001). Attitudes towards questioning and verbal instruction during the learning process vary across cultures and seem to be indicative primarily of which skills or attributes those cultures particularly value (Paradise and Rogoff 2009). Any attempt to classify learning patterns into a strict binary are by definition reductive and overlook the inevitable nuances of the ethnographic record.

With these cautionary words in mind, it is still possible to sketch out certain broad characteristics that one might expect to be diagnostic of different learning traditions. Artifacts produced by novice crafters in cultures which prioritize observational learning should show signs of more experimentation in form, creation process, or design. Additionally there should be little to no signs of collaboration between novices and masters on a single artifact. Novice productions should be made of lower quality raw materials, though this alone cannot be used to identify the presence of novice crafters. By contrast cultures with more directed traditions of learning should leave behind artifacts that show signs of being worked both by novices and experienced crafters. Artifacts created purely by novices should be crude but still display a fundamental understanding of the process behind artifact creation and be recognizable attempts at recreating the forms and styles made by masters. Without access to the production process itself it will, naturally, be often difficult to tell with any certainty how the learning process was undertaken and what the specific customs dictated was the appropriate fashion for novices to acquire craft skills, but the archaeological record can still help unravel some of the lingering questions.

Before examining the Paleolithic record itself, it will be helpful to pause and apply these criteria to more recent archaeological sites for which existing ethnographic or experimental data exist to provide outside evidence. Stout (2002) examines traditional stone knapping apprenticeships among adze makers in Irian Jaya. Novice knappers are tightly scaffolded and given significant help as they learn the craft, with masters offering everything from verbal advice to physical assistance and occasionally even taking over a part of the task entirely. In looking at both the creation process of the adzes and the finished products themselves, Stout is able to draw clear links between the archaeological material and the cultural processes behind it. Adzes produced by novice knappers alone are smaller than those made by masters and display many mistakes common to inexperienced knappers, such as imprecisely aimed blows and battered platforms. They display formal irregularities, particularly in the thickness of the finished product in relation to its length and the flake scars demonstrate a certain caution from the knappers about flaking difficult surfaces such as obtusely angled platforms (Stout 2002). However, these mistakes occur primarily on adzes created solely by an inexperienced knapper. Stout chose only adzes worked on by one knapper for his analysis, but reported that under ordinary circumstances knappers regularly helped each other with difficult portions of their work. Usually this help is offered to apprentices by more experienced knappers, and this process often corrects novice mistakes to the point of rendering them invisible in the finished product (Stout 2002). Though this process is hard to detect in the archaeological record, the formal resemblance between apprentice products and those of more experienced knappers points to a formalized and communal learning process. All adzes produced by novice knappers approximate the shape of those created by masters, with the primary variations being in technical skill and adze size. Given the ethnographic information collected this is unsurprising – novices and masters work alongside each other and communicate regularly. As the adzes themselves are ritualized and regulated items, any notable formal variation, whether accidental or by design, will rapidly be detected and corrected by an accompanying knapper.

Most crafts that traditionally depend heavily on observational learning, such as weaving or sewing skills, are ephemeral. Thus it can be difficult to find case studies in the archaeological record for this form of knowledge transmission. The most easily preserved types of crafts are stone artifacts and pottery, and in both cases ethnographic research shows that some form of scaffolding is nearly always used, if only minimally. Crown (2001) provides ethnographic data stating that young Pueblo potters habitually learn their craft through observation and imitation, but her analyses of pots found in the archaeological record show evidence of scaffolding and collaboration between novices and experts, particularly in the pots' final decoration. Lave (1982) describes a primarily observation/imitation method of learning among apprentice tailors, but their work is easily dismantled and does not preserve. Much of the literature surrounding observation/imitation learning deals only indirectly with either crafts or the archaeological record or both, focusing instead on social or language skills and extrapolating from there. However, evidence does exist for cultural traditions using varied forms of learning, the remains of which may be possible to classify into different types. Prehistoric ceramic artifacts found in the Northern Arizona region of Sinagua show a wide range of skill levels, including some artifacts made by obvious beginners (Kamp 2001). Among these artifacts are clay animal figurines, likely used as toys for children. Though some of these figurines display expert craftsmanship, most seem to have been made by amateurs or even beginners, as evidenced by the cracks from firing and the improperly attached limbs (Kamp 2001). These also show signs of children's fingerprints, as determined through analysis of the space between troughs and ridges (Kamp 2001). Though there is no concrete proof for the theory, it seems likely that young children made these figurines for themselves, either with direct guidance from adult ceramists or on their own. Ethnographic evidence suggests the latter option for the most part; a large majority of potters from around the world prefer to let children experiment on their own first before offering any formal instruction or even significant help (Kamp 2001; Kramer 1997). Larger vessels, such as the corrugated bowls made by experienced potters for daily use, occasionally also show children's fingerprints, but they are technically sophisticated and otherwise indistinguishable from bowls made by adults. No evidence exists to determine whether or not these bowls – or the smaller bowls that seem to be an intermediate step between beginning ceramics and expert productions – were made with the benefit of more direct instruction.

Though these examples are not perfect, they serve to show that it is indeed possible to pick out learning mechanisms in the archaeological record. Stout's observations match what we would expect to see in a group that relies heavily on directed learning, namely a regularity of form and technique and clear signs of mutual assistance between novices and experts. The primary differences between the adzes made by the novices and those made by experts are in the sizes of the pieces and the choice of which flakes to attempt, differences which make it clear how skilled the creator of any given adze was but do not show any signs of trial and error from novices. The clay figurines discovered in Sinagua, however, show variation in form and technique as well as skill level, signs of experimentation or uncertainty on the part of the creators. In both cases, ethnographic evidence matches the conclusions drawn by examining the archaeological evidence, suggesting that attempting to draw such conclusions from archaeological materials is possible even without ethnographic data to bolster results. I turn now to the Paleolithic record, for which no ethnographic data exists at all, and will apply the criteria outlined here to speculate about how Paleolithic groups chose to educate their novice flintknappers.

THE PALEOLITHIC RECORD

Lower and Middle Paleolithic

The earliest clear evidence of craft knowledge by hominid ancestors comes in the form of Oldowan tools discovered at Gona, Ethiopia (Semaw et. al. 1997). These artifacts are dated to 2.5mya, and the species responsible for their creation is still uncertain, though the leading candidates are *Australopithecus Garhi*, due to fossils found associated with similarly aged tool deposits in other sites nearby, and *Homo habilis*, often considered the first toolmaker (Semaw 2000; Ambrose 2001). Like all Oldowan tools, the artifacts recovered at Gona are crude but clearly made by individuals in possession of both technical and practical knapping skills. Modern human knappers are capable of reproducing Oldowan tools within a few days to a few weeks of practicing, with learning curves depending on their innate levels of strength, depth perception, and hand-eye coordination as well as the amount of instruction available to them (Jones 1981; Sheets 2013). Even mediocre knappers are usually able to master the required techniques using only observational learning, though it generally takes them longer than novices who are given verbal or demonstrational instruction, and self-taught knapping pioneers discovered the techniques required to produce Oldowan tools without any instruction or opportunities for observation at all (Apel 2008; Flenniken 1984).

A qualitative difference exists between Oldowan tools and later, more sophisticated technologies. The transition from one to the other was not merely a result of technical refinements and increased theoretical knowledge on the part of knappers across generations. Indeed, many of the technical skills required to make tools of either type are extremely similar (Faisal et. al. 2010). Instead the transition from the earliest technological form to those that followed seems to have involved a cognitive development rather than a purely technical one, notably an increased ability to visualize a final product and the *chaîne opératoire* required to achieve it (Shipton 2010). The earliest Acheulean tools appear in the archaeological record approximately 2mya and they have been found associated with several different hominid types, all of the genus *Homo* (Goren-Inbar 2011). Brain scans of modern knappers show that creating tools more complex than Oldowan activates areas of the brain associated with fine motor control and speech, particularly in the right hemisphere (Faisal et. al. 2010; Shipton 2010). However, given the ancient age of early Acheulean tools, they were most likely created by hominid groups possessing either no or limited language. Though the language capacities of ancient hominid are still debated, the most likely method of information transfer between makers of Acheulean tools is observation/imitation. Once again, however, there exists a qualitative difference between the level of sophisticated observation/imitation required by human and nonhuman ape knappers to make Oldowan tools and that required to make Acheulean style objects. No nonhuman ape has ever been taught to replicate tool technologies more complex than Oldowan, a fact related as much to their poor imitation capacities as to their physical limitations (Shipton 2010). Humans, unlike other primates, have the capacity to imitate complex sequences of behavior accurately and consistently, even when not all steps of the imitated sequence are necessary for the end goal (Arbib 2011). This highly developed ability allows for the natural transmission of culture between humans, and permits even technical skills such as the making of tools to spread through a group and across generations (Arbib 2011; Shipton 2010).

As technological traditions became more complex, the physical and mental demands on the knapper increased. Creating a well-made Levallois tradition tool, for instance, requires an in depth understanding of the core's properties and enough practical and theoretical knapping experience to adapt to any unexpected flaws or mistakes (Schlanger 1996). The switch from using cores as the primary tool to using flakes allowed for a more efficient use of cores but also required more highly skilled knapping. Working with long, thin blades requires more skill than does working with smaller, thicker cores (Stout 2002), and, therefore, it likely took significantly longer to master the techniques needed to make Levallois tools than it did to master earlier technological forms. In addition, refitting work done on Levallois cores shows that the final flakes on each core are detached from the same side and end of the core (Peer 1992). In order to accomplish this, knappers would have had to not only be able to plan their strikes in advance but also to have learned the appropriate way to approach the task. Moreover, those techniques cannot be replicated by complete novices in any recognizable form, requiring instead that novices wishing to produce blades be aided by experts for at least part of the process (Eren et. al. 2011). Though this aid did not necessarily take the form of direct instruction – novices could, for instance, have worked with pre-prepared and discarded cores – the inability of novices to approximate the entire process of blade creation on their own indicates that a purely observation/imitation model of learning would not have been sufficient to transmit the necessary knowledge across generations. Careful refitting of Levallois cores shows that competent knappers had an intimate understanding of the properties of the raw materials used (Schlanger 1996). Finished tools display significant overall formal variation, but this suggests a primary focus on the utilitarian aspects of the tools rather than a lack of skill on the part of the knappers (Mellars 1996). Each flake was chosen based upon how detaching the last had shaped the core, and knappers were able to adapt their techniques to detach increasingly smaller and thinner flakes as the core shrank in size. Experimental knapping projects have demonstrated that this understanding of the raw materials must be learned, and that without instruction novices rarely display even a basic grasp of how to adapt to the changing conditions of the core (Geribàs et. al. 2010).

Unlike Lower Paleolithic traditions, the tools employed by hominids in the Middle Paleolithic could not be independently derived by each person. Moreover, the amount of theoretical and practical knowledge required to successfully detach usable flakes from Levallois cores strongly suggests that novices were not merely absorbing cultural information without influence from more expert craftsmen. Though it seems unlikely that Lower Paleolithic tool traditions were dispersed across populations without deliberate effort or cooperation from the toolmakers, the ability of modern experimenters to replicate Oldowan tradition tools without outside help or guidance means that an observation/imitation model of learning cannot be ruled out. Though a purely imitation/observation model would result in a significant amount of wasted raw materials, owing to the trial and error nature of such a learning method, it is not entirely out of the question. Ethnographic data about modern flintknappers suggests that novices may have at least benefitted from supervision by older or more experienced knappers, but Oldowan tools were not developed by *H. sapiens*, and thus drawing an analogous relationship between ancient and modern toolmakers is difficult. Ethological observations of modern apes show a predominantly imitation/observation model of learning even when raw materials are scarce. We cannot, therefore, rule out such a method entirely when considering the mechanisms used by ancient *Homo* species to transmit the technical knowledge necessary to make Oldowan tools.

By contrast, no experimental or modern conditions have allowed knappers to teach themselves techniques of the Middle Paleolithic without any guidance. The Levallois technique is primarily associated with *Homo neanderthalensis* rather than with *H. sapiens*, though comparable techniques have been associated with *H. sapiens* in Africa (Wynn & Coolidge 2004). Levallois cores have also been discovered alongside *Homo heidlebergensis* remains at sites in South Africa dated to approximately 500kya (Wilkins et. al. 2004). Increasing amounts of archaeological evidence suggests that ancient *H. sapiens* were cognitively similar, if not identical to modern humans (see McBrearty & Brooks 2000 for an overview). Thus, as modern humans are incapable of learning the necessary flaking techniques without direct assistance or guidance, it seems extremely likely than ancient humans would have had the same limitations. Furthermore, research into the cognitive capacities of Neanderthals suggest that the differences between Neanderthals and human were likely minimal, probably concentrated in areas of problem solving and working memory (Wynn & Coolidge 2004). The underdeveloped working memory in particular suggests that novice knappers did not pick up the skill necessary to create Levallois tools through observation/imitation. Successful imitation requires the imitator to keep an image of the process used to create an object fresh in their minds as they work, a cognitive process that requires a well developed working memory (Wynn & Coolidge 2004). Suggesting that ancient humans and Neanderthals taught each other to make sophisticated stone tools through methods more involved than pure imitation/observation serves as further evidence that the so-called human revolution of the Upper Paleolithic may not have been as clear cut as traditionally assumed. This method of learning is a clearly cultural one, indicative of a high level of cognition not seen in other primates. Furthermore, the amount of time required to master Levallois techniques, a period of several years (Mellars 1996), implies that the social organization required to transmit knowledge through instruction was long term, if not permanent, and at least somewhat structured. That structure becomes obvious later in time, with clear archaeological evidence at certain Upper Paleolithic sites pointing to social organization if not hierarchy, but its roots stretch at least back into the Middle Paleolithic in both Africa and Europe.

Upper Paleolithic

By the start of the Upper Paleolithic in Europe, tool technologies had diversified and specialized (Bar-Yosef 2002). Different technologies are associated with different cultures, a testament to the fact that the variation between these technologies is far more stylistic than practical. Some tools appear to be as much aesthetic objects as functional ones, testament to their makers' fully developed capacity for symbolic thinking. Novices of each culture learned the particular traditions and techniques of their groups, a process that likely took several years due to the complexity and culturally specific nature of the techniques being transmitted. Furthermore, the composite technologies that had emerged in the Middle Paleolithic, such as hafted spears, became increasingly refined and complex over the course of the Upper Paleolithic (Wilkins et. al. 2012). These new technologies undoubtedly required more time and a higher level of theoretical knowledge to learn than existing single-component technologies. Unfortunately, no part of these composite tools still exist except the hard projectile points, usually made of bone or stone, and so recreating the process used to make the entire tool with any kind of certainty is currently not possible.

Archaeological evidence from this period shows undeniable evidence of complex societal structures and several sites have been identified as possible "schools" of flintknapping, or areas in which both novice and expert knappers worked alongside each other. These sites provide modern researchers with invaluable looks into this aspect of social organization. However, it is important to remember that Upper Paleolithic peoples were no more monolithic in their cultures or attitudes than are modern peoples, and thus each site can be seen only as a clue to the social organization of that particular group, rather than as a way to make blanket statements about the Upper Paleolithic as a whole. Instead, I present the following case studies as an example of how the record can be used to make inferences about cultural specifics. Unlike the examples in the previous section, these sites were populated by anatomically and cognitively modern humans. Therefore, differences between groups are far more likely to be cultural than to be caused by cognitive differences. Practical considerations cannot be ruled out – scaffolding-heavy learning models can in some cases be attributed as much to scarcity of raw materials as to cultural values, for instance – but even those practical considerations are acts of culture. The purpose of these case studies is not to make any concrete statements about the values of the groups in question, but rather to show that differences in learning models can be determined from specific sites as well as from more general theorizing.

Pincevent

The Upper Paleolithic site of Pincevent sits in the French Parisian basin (Piegot 1987). It consists of a temporary habitation site, likely inhabited for a few months, and contains several hearths as well as significant amounts of debitage from the production of lithics (Julien et. al. 1987). Faunal remains found in and around the dwelling spaces suggest that the inhabitants were nomadic reindeer hunters, and it has been suggested that the site was inhabited by different groups at different times (Leroi-Gourhan & Brezillon 1966; Pigeot 1987). Of interest here are the lithic artifacts, which show clear evidence of varying levels of technical competence within the group (Pigeot 1990). The lithic materials found at Pincevent consist primarily of blades and associated debitage (Leroi-Gourhan & Brezillon 1966). A particularly high number of large and intact blades have been found, causing some to suggest that they may have been an end in and of themselves for ancient knappers (Pigeot 1987). Most of these blades were knapped on site, but a minority do not have associated debitage and seem to have been brought to the site already formed (Leroi-Gourhan & Brezillon 1966). Interestingly, many of these blades do not seem to have been used, and the site is bare of weaponry that might have enabled the inhabitants to hunt large game (Leroi-Gourhan & Brezillon 1966).

The lithic materials found in and around dwelling U5 show very clear variation in skill level and seem to have been produced by the same occupation. Though the debitage found outside the dwelling seem to have been made by expert knappers alone, the archaeological materials from within the dwelling contain debitage from knappers of all skill levels (Pigeot 1987). It is easy to differentiate between expert, intermediate, and novice knappers, both through the debitage itself and through the spatial organization of the site. The knappers appear to have worked in ring-like shapes, with the most highly skilled knappers sitting closest to the center of the dwelling, near the hearth. Around them seem to have been more intermediate level knappers, while debitage from unskilled knappers is found still further away from the center (Pigeot 1987).

Some form of hierarchical organization can be inferred by this pattern, but interpreting the cultural reasoning shaping such a hierarchy can only be speculation.

The debitage itself very clearly communicates the skill levels of the knappers. Long blades such as the ones being produced in dwelling U5 are difficult to make and even more difficult to correct after a mistake, requiring careful attention from the knapper at every step of the process (Pigeot 1990). Many of the assemblages left by more experienced knappers are lacking the final blade, indicating that the tool was either moved from the production area or used and eventually discarded (Pigeot 1990). By contrast, debitage assemblages displaying lower levels of skill are generally intact, allowing for full refitting of cores. Some of the blades produced by these knappers are whole and complete, if clumsily made, but no signs exist that they were ever used in any capacity. They seem to have been created exclusively for the sake of creating them, which suggests an educational context to the exercise. Pigeot (1990) refers to these novices as 'apprentices,' suggesting that some level of verbal instruction may have been necessary to complete the more intricate parts of the knapping process. By the distribution of the assemblages it would not appear that experts worked directly and exclusively with novices – no traces of expert intervention can be seen in the novice debitage assemblages. Though it may be that novices went to where the experts sat for more direct demonstrations, Pigeot (1990) claims that the early stages of the knapping process would not require it. Ferguson (2008) and Eren et. al. (2011) provide anecdotal evidence in support of this claim. Both break down the knapping process for sophisticated stone blades and assert that the early stages can be learned through observation/imitation alone, though all the authors agree that the later stages cannot be successfully learned without some form of instruction.

Further evidence for the hypothesis that early stages of learning occur through observation/imitation comes in the form of a fully refitted core (N236). The knapper seems to have only partially understood the process involved in preparing the core, resulting in seemingly arbitrary blows and a demonstrable lack of adaptation to the core's changing state (Pigeot 1990). Replication without full understanding is a hallmark of observation/imitation learning. Observation, particularly observation from a short distance away, allows novices to replicate gestures and even sequences of gestures, but cannot always provide the logic behind those gestures or the circumstances under which they should be used. Stone knapping has no golden formula: while the rough sequence of tasks remains the same across different projects, each core must be approached on its own merits and considered according to its own strengths and weaknesses rather than according to a predetermined sequence of tasks. A novice who has observed experts using a certain motion or preparing a core a certain way may not possess enough technical understanding of the knapping process to judge whether or not that gesture should be used on their own core or not. Furthermore, the most effective way for a novice to learn to adapt to the materials is likely to allow that novice to make their own mistakes. Experts may not have found it necessary to correct novices in environments containing abundant raw materials such as Pincevent.

We can theorize, therefore, that much of the early transmission of knapping information at Pincevent was likely done through observation/imitation learning, with perhaps some instruction as novices became skilled enough to attempt the most difficult parts of the process. No evidence exists for experts and novices collaborating on the same core, nor are there any debitage assemblages that would indicate a novice and an expert working side by side even for a short time. The abundance of lithics at the site and the presence of unused blades with the novice assemblages in particular suggest an emphasis on the knapping process rather than the end product, potentially for educational purposes.

Solvieux

The site of Solvieux sits in southwestern France and contains a unique stone tool tradition called the Beauronnian (Gaussen 1996). It was among the earliest open air Paleolithic sites to be found in France and shows several different layers of occupation (Gaussen 1996; Koetje 1994). The site contains fourteen different levels of habitations, displaying lithic material from the Beauronnian, the Aurignacian, the Perigordian, the Solutrean, and the Magdalenian (Gaussen 1989). The level which interests us here is the Perigordian level, which contains evidence of a novice knapper potentially working with experts in order to remove a blade from a flawed core (Grimm 2000). Unlike at Pincevent, the Perigordian level at Solvieux shows no signs of a hearth and may have been used by groups of foragers rather than hunters (Koetje 1994). It seems to have served as a short term habitation space for several different groups, or possibly the same group several different times, rather than as any form of semi-permanent or seasonal campsite (Koetje 1994).

Evidence of novice knapping at the Perigordian level comes from a single core, Core 5 (Grimm 2000). This core shows signs of work by both a novice and an expert knapper, and its debitage is spatially distributed in a way that suggests that the novice may have gone to expert knappers for help at certain points in the reduction process (Grimm 2000). The core itself is of low quality and seems to have been discarded by an expert knapper and recovered by the novice for their own use. Unlike many novice cores, Core 5 was worked until completely exhausted despite the flaw that likely created significant problems for the knapper. Refitting the debitage to the core shows that the novice knapper lacked finesse in their technique, choosing strength of blows over delicacy and detaching large, thick flakes that often ended in hinge fractures (Grimm 2000). Despite the crude technique, the flakes produced by the novice are similar enough to those produced by expert knappers to suggest that the novice was hindered primarily by a lack of experience rather than a lack of knowledge. The novice knapper seems to have had a good grasp of the appropriate *chaîne opératoire* and merely lacked the technical skill to properly put their theoretical knowledge into action.

The spatial distribution of Core 5's debitage suggests that the novice moved several times during the reduction process (Grimm 2000). All three locations at which debitage from Core 5 were found also contain debitage from more expertly worked cores, though the association is not strong enough to draw more than speculative conclusions about the relationship between the knappers. However, the removal of a crested blade from the core provides much stronger evidence of a relationship between the novice and at least one experienced knapper, as the blade removal process seems to have been undertaken by an expert (Grimm 2000). After the blade was removed the novice continued to work the core, suggesting that the blade removal did not occur after the novice had discarded the core for any reason. Thus, the novice worked closely with at least one expert on at least one occasion.

As only one novice core has been identified, it is hard to draw any firm conclusions about how the Perigordian inhabitants of Solvieux transmitted their knowledge across individuals. The data provided by Core 5 is anecdotal at best. However, that does not render it valueless – even if it proves to be an exception to the general trend of knowledge transmission among Perigordian nomads, the fact that Core 5 was worked by both a novice and an expert shows that such collaborations were not entirely unknown. Furthermore, that evidence coupled with the novice's apparent grasp of the theoretical knowledge needed to properly remove flakes from the core, suggest a close association between the novice and at least one expert. It seems plausible, then, to suggest a knowledge transmission leaning more towards scaffolding or instruction than pure observation/imitation. Though the novice's use of an already discarded core seems indicative of a more imitation based learning system, the rest of the core's history points to a closer relationship between novices and experts. In particular, the removal of the crested blade by an expert knapper points to a system of knowledge transmission wherein novices were at least permitted if not encouraged to ask for assistance. Many purely observation/imitation learning systems discourage novices from bothering experts as they work and encourage them to figure tricky steps out on their own (e.g. Lave 1982; Kramer 1997). Ethnographic evidence points to a close relationship between direct assistance from experts on a particular piece and a larger system of scaffolding (e.g. Stout 2002). Furthermore, the novice knapper seems to have been in possession of enough theoretical knowledge to know what they were supposed to do, though they lacked the practical experience to know exactly how to do that. This stands in contrast to situations wherein the novice may have learned how to execute certain steps due to observing experts at work but lack the theoretical grasp of why those steps were necessary. The evidence at Solvieux does not appear to correspond to a novice lacking a grasp on the full process but rather points to one who understands what to do and why to do it but has not yet mastered the physical skills necessary to do each step well.

It would be premature to declare the Solvieux Core 5 evidence of any form of formal apprenticeship system. However, some form of deliberate transmission of information seems undeniable. Nor does there appear to be the same clear hierarchy of knappers that there was at Pincevent, suggesting perhaps that novices were invited to participate more fully in the communal knapping process. Again, though this is not enough evidence to make any claims about the formality of the Solvieux system, it suggests a higher level of involvement from expert knappers in the learning process. No technical reason exists why the blades made at Solvieux should require more scaffolding than those from Pincevent; the difference seems to be a purely cultural one.

Summary of observations

In examining the archaeological record of the Paleolithic, we see that no clear indication of directed learning appears until the emergence of the genus *Homo*, and more specifically not until the development of Levallois cores and similarly complex tool technologies. While earlier technologies such as Acheulean handaxes may have been transmitted through directed learning as opposed to an observation/imitation model, clear evidence does not yet exist to support that conclusion. Without clear evidence, no conclusions can be drawn one way or the other regarding how Acheulean technology was transmitted across and within groups. With the development of Levallois cores and hafted weapons, however, the likelihood of at least some part of the learning process being directed increases substantially. Though modern humans have a capacity for imitation unrivaled by any extant ape (Shipton 2010), they cannot successfully learn to knap blades according to the Levallois technique without direct instruction. Given the development trajectory of human cognition, it seems unlikely that extinct species of *Homo* would possess a more sophisticated capacity for imitation than do modern humans, particularly as evidence suggest that Neanderthals had less well developed working memories than do humans.

Neurological research has linked the fine motor control needed to make complex stone tools with the fine motor control needed for spoken language. Similar research has shown that the development of Acheulean tools represented not just a technological breakthrough but a cognitive one as well (Arbib 2011). It is therefore logical that a change in learning model would accompany these other changes, thus marking a boundary between proto-human cognition and that of other apes. Once again, the archaeological evidence does not currently exist to support the idea that Acheulean technology was transmitted via a method other than observation/imitation, thereby making this idea nothing but speculation. Only with the development of Levallois and equivalent technologies does the physical evidence support the idea of a shifted learning model. Until similar evidence can be uncovered about more ancient technologies, it seems prudent to suggest that those technologies were transmitted between individuals via the more ancient model of observation/imitation, a process which likely benefitted significantly from the growing imitative capacities of the genus *Homo*.

By the Upper Paleolithic, ancient *H. sapiens* had become undeniably cognitively and anatomically modern. The tools they created were technologically sophisticated and culturally distinct, and the methods they used to transmit the knowledge of how to make those tools was almost certainly equally dependent on culture. Though using analogies to extant cultures to describe the behavior of ancient humans is scientifically dubious, it seems safe to suggest that ancient cultures were as diverse in their values and their organizations as are modern ones. Thus, we should expect to find variation in how technological knowledge was passed on, with some groups favoring a more observation/imitation heavy model and others relying more on direct scaffolding or instruction. Naturally, these models exist on a continuum, dependent as much on practical factors such as availability of raw materials and group composition as on culturally determined values and traditions, but cultural differences between groups play a large part in dictating where on the spectrum each group falls.

In examining two different Upper Paleolithic sites I found that it was indeed possible to detect potential differences in learning models between groups. Though these differences cannot with absolute certainty be attributed purely to cultural differences, owing to the different lifestyles of the two groups and the unknowns surrounding their composition, history, and situation, the fact that those differences do exist is undeniable. Given ethnographic and experimental data, it seems likely that the differences between the two sites are at least in part attributable to cultural variation between the two groups, as no obvious technological factors have been found that might influence the choice of learning model. Two sites is not nearly a large enough sample size to say anything concrete, particularly as one site has only one novice core, but the data these sites offer are enough to suggest that further investigation would be warranted, both at other Upper Paleolithic sites and at older ones.

CONCLUDING DISCUSSION

This project examined the archaeological record of the Paleolithic through the lens of cultural transmission and, in doing so, drew parallels between past cultures and more modern ones. Naturally, these parallels are not exact, and no modern culture should be treated as perfectly analogous to even their own past. However, they do offer a starting point and comparison. Combining ethnographic data with information collected about the behavioral patterns of nonhuman primates provide anthropologists with boundaries for reasonable variation in the past, as well as with ideas about which behaviors are biologically based and thus more likely to be universal. Using those boundaries as starting points, archaeologists can make more informed deductions about the particulars of past societies, as well as speculate about which aspects of society are likely to have been particularly affected by individual cultures. One of those aspects appears to be the transmission of craft knowledge. Though common anthropological wisdom has painted craft learning as, if not identical, then certainly similar across cultural boundaries, a more careful look at the available data suggests that the methods used are more varied and culture-specific than once believed.

Even with the broad strokes approach of this study, I was able to determine that variability in learning method can be visible in the archaeological record. Further, I was able to suggest that a more guided model of learning may be far older than commonly thought, perhaps pre-dating the emergence of *H. sapiens* entirely. This conclusion holds significant implications for future cognitive archaeology work, as it speaks to the social and intellectual capacities of ancient *Homo* ancestors, particularly *H. neanderthalensis* and *H. heidlebergensis,* the latter of which is thought to be a direct ancestor to modern humans. If ancient *Homo* ancestors possessed the ability for at least some form of teaching, it follows that they likely also possessed sophisticated language skills and a working theory of mind, as well as the already theorized highly developed capacity for imitation and long term memory. I was also able to examine Upper Paleolithic sites and determine a likely model of learning used by the inhabitants of each site. These case studies are both interesting in and of themselves and also serve as proof that learning models can be detected in the archaeological record and are thus potentially available for study. Like all cognitive archaeology it remains a more speculative area of study than other aspects of Paleolithic culture, but I believe it to nevertheless be a valuable one.

Naturally, further study will be needed to draw any definite conclusions about how craft knowledge was transmitted within various Paleolithic groups. The information presented here is merely a preliminary overview, an experiment designed to see whether or not such information was even possible to collect. In doing this research I was not able to visit any sites or examine any artifacts first hand, which forced me to rely on the interpretations of others, thus limiting the usefulness of my conclusions even further. However, despite those limitations, I was able to draw some tentative conclusions and, I believe, show that in certain cases it may be possible to trace not only what individuals in past societies learned but how they learned. The archaeological record, while imperfect, holds enough clues that we can at least make an effort at reconstructing how societies in the past functioned and even, on occasion, what they valued. Through studying patterns of knowledge transmission, we can learn about cultural norms and the specific roles that may or may not have existed in the past. While we may never reach the level of detail attained through interviews or observation of living people, we can still look at how patterns differed across cultures and, through that variation, suggest larger cultural differences. Clearly, the pattern of novice-expert interactions seen at Pincevent differ from the ones seen at Solvieux, and, though we may not be able to determine exactly how or why those differences occurred, even knowing that they exist allow us to paint a far more nuanced picture of the European Paleolithic. This study serves to further our understanding of the past by reminding us that no culture or time period is monolithic, and that human societies are guided by far more than simple environmental factors.

Expanding this project further would require both a more in depth study of the archaeological record itself and a more careful examination of modern learning patterns. The models of learning used here were, by design, quite broad. Within both an observation/imitation model and a directed learning one there are as many nuances as there are extant cultures, and we should not expect anything less of the past. It may, however, be necessary to use broader strokes when looking at past societies than we would doing purely ethnographic research, simply because far less of the whole picture is available for study and thus we cannot access all the nuances involved in cultural practices. It may be that when dealing with the archaeological record, we cannot simplify methods of knowledge transmission far beyond the overarching models used in this project. However, even if this is the case, further research would allow trends to emerge and connect past societies to present ones in more nuanced ways.

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