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Factors affecting Acheulean handaxe variation: Experimental insights, microevolutionary processes, and macroevolutionary outcomes

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ABSTRACT

The "Acheulean" is comprised of individual knapping events undertaken by individual hominins. In other words, it is a particular component of hominin behavior that we draw out and amalgamate into a wider "pattern." The resultant phenomenon (i.e., "the Acheulean") is an entity that stretches over the space of three continents and spans a time period in excess of one million years. If such an exercise has any merit, it is because it provides a means of comparative (behavioral) analysis over these swathes of time and space. Comparative research can document, measure, and statistically assess temporo-spatial patterns of artifactual variation, and so test hypotheses regarding the character of that variation. However, it does not provide an independent means of examining some of the key phenomena which it is necessary to further understand in order to increase our comprehension of this archaeological legacy. Here, we review and synthesize recent experimental work that we have undertaken, which has specifically investigated some of the factors potentially responsible for the generation and constraint of variation within the Acheulean techno-complex. We examine issues of raw material, copying errors, and their relationship to mechanisms of social learning. Understanding these microevolutionary factors via experiments, we contend, is essential in order to reach a secure understanding of the macroscale phenomenon typically referred to as the "Acheulean." Moreover, we outline how a "quantitative genetic" framework to these issues provides an essential means of linking these inherent micro- and macro-evolutionary factors into a coherent whole, while also simultaneously reconciling the potential influence of different sources of variation that are part of a temporally and geographically dispersed entity such as the Acheulean.

1. Introduction

Beginning around 3.3 million years ago (Harmand et al., 2015), the first 1.6 million years of knapped stone tool technology consisted of cores and the sharp flakes struck from them (Semaw, 2000; Roche, 2005; Schick and Toth, 2006). Despite their seeming simplicity, the routine production of such cutting tools appears unique to the hominin lineage (Roux and Bril, 2005; Shumaker et al., 2011), and consequently, this technological innovation is regarded as a fundamental step along the journey toward the eventual emergence of our own species (Isaac, 1983; Shipman and Walker, 1989; Ambrose, 2001; Rogers and Semaw, 2009). From around 1.7–1.5 million years ago, however, hominins began to produce entirely new forms of artifacts, most notably, so-called "handaxes" (Lepre et al., 2011; Beyene et al., 2013). The production of these novel artifacts marked a shift away from cores and nodules simply being items that were struck in order to produce flakes, to a situation where knapping events were strung together in a manner that resulted in a characteristic residual form—i.e., the "handaxe" (Roche, 2005; Gowlett, 2006). Although much remains to be learned regarding details of their functions and applications in specific circumstances, in general terms, the archaeological contexts of such artifacts, residue analyses, cut-mark analyses, design theory, and experiments, combine to suggest they plausibly performed a variety of functions as cutting and/or chopping tools (Jones, 1980; Roberts and Partfitt, 1999; Domínguez-Rodrigo et al.,

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2001; Simão, 2002; Gowlett, 2006; Bello et al., 2009; Yravedra et al., 2010; Solodenko et al., 2015).

Following their initial appearance, the production of handaxes was an activity undertaken by hominin populations for over one million years (Gowlett, 2011; Haslam et al., 2011; Beyene et al., 2013). Moreover, hominins engaged in production of these tools over a geographic range that stretched from South Africa to Britain, and from the Iberian Peninsula to the Indian subcontinent (Clark, 1994; Wynn, 1995; Schick, 1998; Gowlett, 2011). It is now clear that definite pockets of handaxe production took place east of the so-called "Movius Line," even if debates regarding the chronology, comparability, and relationship of these East Asian examples rumble on (Hou et al., 2000; Norton et al., 2006; Lycett and Gowlett, 2008; Petraglia and Shipton, 2009; Norton and Bae, 2009; Lycett and Bae, 2010; Li et al., 2014; Wang et al., 2012, 2014). Rightly or wrongly, the geographic and temporal expanse of these characteristic artifacts has famously been referred to in the collective as "the Acheulean" (Wynn and Tierson, 1990; Schick, 1998; Gowlett, 2011). As recent commentators have noted, although this entity has curiously been defined in a variety of different ways over the years, it is the presence of handaxes more than any other criterion that tends to lead to a particular site or assemblage being characterized as "Acheulean" (Lycett and Gowlett, 2008; Diez-Martín and Eren, 2012; Domínguez-Rodrigo et al., 2014).

By any standards, the "Acheulean" is a phenomenon that evokes immediate questions. In basic terms, it simply represents a pattern of repeated hominin behavior (i.e., biface production) over the course of one million (plus) years over three different continents. This repetition of handaxe production is, of course, likely driven by shared functional needs on the part of its producers over time and space; as Gowlett (2011: 100) put it, "a culturally maintained set of functional solutions to everyday tasks which recur." However, that commonality of behavioral pattern—at least in general terms—provides a basis for comparative research at the archaeological level (Wynn and Tierson, 1990; Vaughan, 2001; Lycett and Gowlett, 2008; Petraglia and Shipton, 2009; Chauhan, 2010; Wang et al., 2012). In other words, an essential part of studying the Acheulean is to understand its potential variability, both in temporal and geographical terms. Comparative research can document, measure, and statistically assess temporo-spatial patterns of artifactual variation, and so test hypotheses regarding the character of that variation. However, we contend that experiments are an additional but vital way in which the mechanisms that both generate and constrain variation within the Acheulean can be more securely understood. Here, we review and synthesize recent experimental work that we have undertaken, which has specifically investigated some of the factors potentially responsible for the generation and constraining of variation within the Acheulean techno-complex. We relate our discussion of this experimental work to cultural microevolutionary considerations, which specifically relates patterns of variation to issues of social learning. The Acheulean has long been seen as being of a rather paradoxical character in that it possesses both variation and stability (Isaac, 1972; Gowlett, 1998). As we aim to show in the closing sections of this paper, a "quantitative genetics" framework to this issue can help to integrate an understanding of localized, microevolutionary processes with the wider scale, macroevolutionary pattern referred to as "the Acheulean." In particular, we introduce a quantitative concept of "heritability" drawing on evolutionary quantitative genetics principles developed in biology. This concept reconciles how different sources of heritable and nonheritable variation (e.g., culture, raw material, and reduction factors) can potentially be of influence under the same framework. Indeed, it highlights how microevolutionary factors both facilitate and constrain variation within the Acheulean. In closing, therefore, we show how an understanding of these issues is an essential element in understanding Acheulean temporo-spatial variation, and the constraint of that variation, in cultural evolutionary terms. In other words, this synthesis of various experimental findings and microevolutionary principles provides insights regarding the Acheulean at the macroevolutionary level.

2. Acheulean variation in the raw: toolstone "constraints" investigated experimentally

Raw material factors have long been considered to exert an influence on the form and composition of lithic assemblages (Goodman, 1944), and the role of raw material has been frequently deliberated over in specific regard to variation within the Acheulean techno-complex (e.g., Isaac, 1977; Jones, 1979; Wynn and Tierson, 1990; Roe, 1994; Schick, 1994; Clark, 2001; Noll and Petraglia, 2003; Sharon, 2008; Archer and Braun, 2010; Costa, 2010; Wang et al., 2012; among many others). The suspected link between lithological factors and resultant artifactual form is, of course, a logical outcome of the fact that the medium with which any artisan is working might have properties that affect given outcomes. Both the internal and external properties of rock types have been considered within the context of such debates. In the case of a rock's internal characteristics, factors such as isotropy, homogeneity, brittleness, hardness, and granularity have frequently been considered pertinent, all of which ultimately relate to the mineralogy and microstructure of particular rock types (Goodman, 1944; Callahan, 1979; Whittaker, 1994; Andrefsky, 1998). External characteristics that may be relevant include the size, shape, and regularity of the material to be knapped, as well as whether cortex is present or absent on the rock's surface (Ashton and McNabb, 1994; Jennings et al., 2010; Smallwood, 2010; Eren et al., 2011). The presence of cortex is potentially important since it has been shown that rock types possessing cortex may in fact behave in terms of some properties (specifically rebound hardness) in two distinct ways, with cortical material acting as one distinct rock type, while the uncortical surface of the same rock can act more similarly to other rock types entirely (Eren et al., 2014).

The seemingly logical notion that rock variability will be a major, if not the major factor, driving variability in Acheulean handaxe form could, however, be potentially overstated. Artifacts, by definition, involve a behavioral component in their formation. There is obviously a risk of circularity in assuming that just because rock types differ at two different Acheulean localities and the properties of artifacts at those two sites also differ, then causality for the latter must automatically reside in the former. Indeed, based on empirical study of Acheulean assemblages, some have recently questioned the extent to which variability in the forms of artifacts such as handaxes is necessarily driven solely by raw material factors (e.g., Sharon, 2008; Costa, 2010).

As we have noted, however, handaxes are the product of multiple knapping events sequentially strung together in order to produce their characteristic properties (Roche, 2005; Gowlett, 2006). If raw material exerts an influence at each individual flaking event, then such effects will obviously be cumulative, potentially leading to divergent outcomes in differing rock types, even if a knapper is striving toward the same overall goal. A major point to consider here, therefore, is whether differences in the internal and external properties of different rock types automatically conspire to produce statistical differences in handaxe form in such a manner. Addressing this specific question on the basis of the archaeological record alone poses serious challenges, not least of which is that directly relevant factors—such as differing knapper skills and intentions—cannot be observed directly and might also vary from site to site. Experimental approaches to this issue,

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