Chapter 17

Knapping in the Dark: Stone Tools and a Theory of Mind

James Cole, University of Brighton, UK

Address: School of Environment and Technology, University of Brighton, Lewes Road, Brighton, BN24GJ

E-mail: j.n.cole@brighton.ac.uk

Phone: (+44)12-7367-41831

Knapping in the Dark: Stone Tools and a Theory of Mind

James Cole, University of Brighton, UK

Abstract: Understanding the cognitive abilities of our hominin ancestors remains challenging. Recent years have seen many advances, especially new fossil discoveries and the Paleogenetic data that has illuminated the mosaic nature of past hominin interactions across multiple human species. However, the primary route to accessing the behavioral and cognitive worlds of our hominin ancestors still remains firmly rooted in the archaeological record, particularly stone tools, the direct products of hominin actions grounded in the physical, social, and cognitive worlds occupied by the knappers. A theory of mind has long been considered a key component of the human condition, linked to both language and the development of abstract thought. There must therefore be a point (or perhaps multiple points) in our evolutionary history when hominins gained a theory of mind. This ability should, in turn, be reflected in the archaeological record. To date, however, only limited attempts have been made to correlate the two. This paper thus explores the relationship between the various stone tool traditions and theory of mind.

Keywords: Theory of mind; lithic technologies; cognitive evolution; Social Brain Hypothesis; orders of intentionality; Identity Model

Introduction

The Paleolithic archaeological record remains the primary vehicle by which researchers are able to assess the behavioral and cognitive abilities of our hominin ancestors. The Paleolithic covers a period of time that stretches from roughly 3.3 million to 10 thousand years ago (Mya/Kya) (Harmand et al., 2015). Much of this Stone Age is, by definition, focused on lithic tools, due to the fact that non-lithic artifacts generally preserve poorly, though there are a few exceptions (Thieme, 1997; Warren, 1911). In comparison, the record of the last 120 thousand years (Ka) has proved extraordinary for organic artifacts made or modified by a range of hominin species (e.g., d'Errico, Henshilwood, Vanhaeren, & Van Niekerk, 2005; Radovčić, Sršen, Radovčić, & Frayer, 2015; Vanhaeren et al., 2006; Zilhão et al., 2010). Researchers interested in the deep-time origins of our species are united in the desire to understand the way the hominin makers of Paleolithic artifacts thought, behaved, and engaged with the social and physical landscapes that framed their existence.

As such, a long history of theoretical and empirical studies (a small sample of this literature includes Davidson & Noble, 1993; Gowlett, 1979, 1996; Gowlett, Gamble, & Dunbar, 2012; Stout, 2011; Wynn, 1979, 1981, 1985, 1991, 2002) has sought to model how artifact manufacture can illuminate the workings of the prehistoric human mind (but see Stout, Hecht, Khreisheh, Bradley, & Chaminade, 2015 for a useful counter-perspective). Such models often focus on the *chaîne opératoire* of artifact manufacture, including raw material selection, management, and movement; the complexity of knapping reduction sequences and degrees of shaping and refinement; use; and discard. In addition, studies often show a general progression toward increasing technological and cognitive complexity in the *chaîne opératoire* as technology changed from a mode 1 simple core-and-flake-based toolkit to a mode 4 blade-and-prepared-core toolkit (Clark, 1961; Gamble, 2013; Lycett & Norton, 2010). Some of these cognitive models were recently formalized in a volume edited by Wynn and Coolidge (2017), which should prove most informative in advancing our way of thinking about the minds of past hominins.

Predicting Hominin Cognition

Beyond focusing on the details of artifact manufacture, researchers have sought to access past hominin cognition through brain size and predicted social group structure using the Social Brain Hypothesis as a primary framework (e.g., Dunbar, 1998a, 2003, Dunbar, Gamble, & Gowlett, 2010, 2014; Gamble, Gowlett, & Dunbar, 2014). This approach has proven useful for understanding when language may have evolved. Certainly, it has facilitated discussion of whether markers can be detected archaeologically prior to the more obvious signposts of beads and art (Aiello & Dunbar, 1993; Cole, 2015b, 2015c; D'Errico et al., 2003; Davidson & Noble, 1989, 1993; Deacon, 1997; Dunbar, 2007, 1996, 1998b, 2003; Gamble, 2012; McNabb, 2012; Shultz, Nelson, & Dunbar, 2012). With regards to the development of language, it is important to note that in order to achieve an understanding of language (visual or verbal), the ability to mentalize is essential (Dunbar, 1998b; Gamble et al., 2014; Origgi & Sperber, 2000).

Mentalizing is the capability to understand or infer what another individual is thinking (Gamble et al., 2014, p. 18), and it includes a suite of skills referred to by philosophers of mind as "orders of intentionality" (Premack & Woodruff, 1978). Orders of intentionality are a series of self-reflective mental states that form a recursive hierarchy, yielding an ordinal scale of cognitive complexity as more mental states are added to the sequence. For example, from Shakespeare's *Othello* Dunbar (2004, p. 162) illustrates five orders of intentionality: Shakespeare *intended* (1) that the audience *realize* (2) that the eponymous Moor *believed* (3) that his servant Iago was being honest when he claimed to *know* (4) that Desdemona (5) *loved* Cassio. The orders of intentionality and a theory of mind have been correlated, with a theory of mind requiring an individual to imagine two mental states, their own and that of someone else. Therefore, a theory of mind is equivalent to a second order of intentionality.

A theory of mind is one of the most important and fundamental cognitive abilities; it underpins all of the key components that make us human, including language, symbolism, culture, and social organization (Gamble et al., 2014). A theory of mind is often defined as the ability to comprehend the mental state of one's own mind, as well as the mental state of an "other" (Baron-Cohen, 2001) and recognize that the other's mental state may differ from your own (Cole, 2015b). Therefore, a theory of mind is essential to the ability to attribute different mental states, desires, and beliefs to others (Krupenye, Kano, Hirata, Call, & Tomasello, 2016; Premack & Woodruff, 1978) and must consequently underpin the ability to attain a second order of intentionality or higher. Given that orders of intentionality are an ordinal scale, a great deal of cognitive and social complexity can be realized if only a small number of mental states are linked together (Premack & Woodruff, 1978). Modern humans tend to operate at a fifth order of intentionality (occasionally, six for some individuals) (Gamble et al., 2014), so when the orders are applied to the evolutionary record (see below), fifth order is generally taken as the maximum.

Before we can discuss the evolutionary and archaeological record in regards to orders of intentionality and theory of mind, we must first understand which species may have acquired these abilities. There has been much recent debate about whether non-human primates and animals like elephants, dolphins, and corvids have access to a theory of mind. As can be imagined, this is a contentious issue with no straightforward answer. Some suggest that mirror self-recognition equates to a theory of mind (Plotnik, De Waal, & Reiss, 2006;

Povinelli et al., 1997; Reiss & Marino, 2001; Savanah, 2013), though there are valid arguments against such behavior genuinely representing a true understanding of the contents of another's mind (de Veer & Van den Bos, 1999; Nielsen & Dissanayake, 2004). As I have summarized these positions elsewhere (Cole, 2015b, 2015c), I will not reiterate them here. However, it is worth noting that theory of mind experiments tend to be conducted with trained, hand-reared, or captive primates with extensive human contact (Davidson & Noble, 1989), and this human exposure may inherently bias the results of such experiments (see Call & Tomasello, 2008; van der Vaart & Hemelrijk, 2012 for useful summaries of these arguments). I would emphasize that in order to truly assess the cognitive capabilities of our closest living hominid cousins and other intelligent animals, wild populations should remain the focus of such research.

Research from Crockford and colleagues (Crockford, Wittig, Mundry, & Zuberbühler, 2012) suggests that wild chimpanzees genuinely understand when other members of their group are ignorant of knowledge that they themselves possess (in this instance, the presence of a potential predator); presumably, it is on this basis that they communicate a warning to modify the behavior of the rest of the group. This clearly needs further investigation, but there are strong parallels and implications for a theory of mind being present in these primates. A more recent study by Krupenye and colleagues (Krupenye et al., 2016) further suggests that great apes have an implicit understanding of false-belief states that promote their cognitive abilities beyond merely being good predictors of behavior based on external cues (Call & Tomasello, 2008). False-belief state experiments are used with human infants to ascertain a theory of mind (typically, children are able to pass these tests around 4 to 5 years of age) (Gamble et al., 2014), implying that perhaps the great apes in the Krupenye et al. study have an implicit theory of mind. This new work certainly raises intriguing possibilities of shared cognitive behaviors between humans and other extant primates, which have also been suggested elsewhere (e.g., Cheney & Seyfarth, 1990; Seyfarth & Cheney, 2011, 2013, 2017a, 2017b). However, I think Dunbar (2007) is still on the right track when he states that great apes are only just able to achieve second-order intentionality—they do it, but not very well, and not all the time. Therefore, we see theory of mind in great apes as primates hovering on the border of a cognitive barrier, poised to break through. The difference with modern humans, and presumably, some of our evolutionary ancestors, is that we are consciously self-aware that we have a theory of mind. It is the conscious realization of this mental state that in turn acts as a springboard to the higher orders of intentionality.

Without a theory of mind, the ability for abstract thought, language, and symbolic construction remains elusive, and therefore, a lack of a theory of mind must at least partly explain why animal communication is iconic and indexical rather than symbolic (Barbieri, 2010; Deacon, 1997; Peirce, 1974; Wynn, 1995). Though it is fully acknowledged that human communication can be iconic and indexical, the key difference is that we can also easily incorporate symbolism, something other animals struggle to do, if at all. I have provided examples of iconic, indexical, and symbolic communications elsewhere (Cole, 2015c; Cole 2016). In general, however, in the semiotic system offered by Peirce (1974), icons represent through their resemblance to an object, indexes represent by pointing in some fashion (e.g., physical, temporal, causative, etc.) to an object. In contrast, symbols represent through socially or culturally agreed arbitrary conventions. Theory of mind is therefore a critical factor of the human condition, essential to the cognitive separation of primate vs. complexity that can be applied to the hominin fossil and archaeological record.

Orders of intentionality have been projected back onto the hominin evolutionary record using modern-day primate brain sizes and the known brain sizes of fossil hominins. These have been interpolated onto the hominin fossil record based on correlations between frontal lobe volumes, predicted group size, and achievable levels of intentionality as a predictive exercise in estimating hominin cognitive levels (Dunbar, 1992, 2004, 2007; Gamble et al., 2014, p. 146; also see Fig. 17.1). Of note, this represents a fairly broad-brush approach to estimating levels of hominin cognition, as there is very little information regarding population variability within species, given the sparse nature of the fossil record. However, there is still some within-species variability in brain size, as can be seen in Fig. 17.1; the implications of this for cognitive abilities are discussed further below.

[Figure 17.1]

Table 17.1 summarizes the schema of Gamble and colleagues (Gamble et al., 2014, p. 146) for assigning hominins to orders of intentionality and the archaeological record through modes of technology (see Clark, 1961; Gamble, 2013, p. 64, Box 2.3, and Fig. 17.1).

[Table 17.1]

From Fig. 17.1 and Table 17.1, it is clear that previous attempts to assign orders of intentionality to the hominin record is difficult, and brain size variability suggests that some individuals within the same species may have attained different orders of intentionality. This is particularly clear for the Sima de los Huesos hominins (designated as Early Neandertals in Fig. 17.1 based on Meyer et al. 2015, 2016). They are assigned to a third order of intentionality based on their brain size, yet they have been associated with complex behaviors interpreted as possibly ritual in nature (Carbonell & Mosquera, 2006); these are perhaps more indicative of a fourth or fifth order of intentionality, such as has been assigned to later Neandertals. In addition, the resolution of the Social Brain Hypothesis and its application of orders of intentionality do not explicitly take into account the relation between behavioral and cognitive plasticity in relation to brain size (cf. Van Schaik, 2013).

However, this is not necessarily a problem; even within our own species, we do not all operate at fifth-order or sixth-order intentionality. Having this mix of behavioral and cognitive variation within the hominin record is a truer reflection of the complexities of our own evolutionary story. McNabb and Cole (2015) describe the within-species variability in absolute brain sizes as “variable-equilibrium” and see hominin encephalization as a staircase with punctuated increases in brain size (Cole, 2012; McNabb, 2012; Shultz et al., 2012). At a general scale, however, according to the predictions of the Social Brain Hypothesis, it appears that the Australopiths, Paranthropines, and early members of the *Homo* genus (*H. rudolfensis* and *habilis*) would have a theory of mind or second order of intentionality. Once *H. ergaster* and *H. erectus* appear, a third order of intentionality has been attained, which seemingly corresponds to the appearance of mode 2 or bifacial handaxes in the archaeological record. A fourth order of intentionality remains the preserve of *H. heidelbergensis* and the Neandertals, broadly corresponding to the emergence of mode 3 prepared-core technology, with *H. sapiens* attaining a fifth order and mode 4 bladed prepared core technology.

Returning briefly to the language question, it seems unlikely that a fully developed ability for grammatical language emerged in hominin cognition at the same time a theory of mind was realized. I have previously proposed (Cole, 2015c) that a developed ability for language based on symbolic interaction incorporating material culture not only requires a second order of intentionality but may only be truly attainable with third-order intentionality. Under the schema of Gamble and colleagues (Gamble et al., 2014), this suggests that *H. ergaster* and *H. erectus* would have had a language system (Gowlett et al., 2012), probably based on non-verbal communication and visual display (McNabb, 2012). This capability would certainly make sense for a group of hominins that managed to disperse across most of the Old World and successfully adapt to a range of (albeit similar; Dennell, 2004) environmental conditions. However, a system of communication based on directed gestures and vocal punctuation is almost certainly possible with a second order of intentionality. It is only with a fifth order of intentionality that a full comprehension of the symbolic abstract occurs, and grammatical language or speech subsequently develops as a selective advantage to allow the expression of the symbolic abstract. Grammatical language is required to explain complex notions between individuals and groups in a way that facilitates an equal understanding. Non-verbal visual display utilizing the body or material culture is simply not expressive or plastic enough to convey the full meaning of a totally abstract notion such as, for example, the supernatural. Recent work by Shultz and colleagues (Shultz et al., 2012) suggests that grammatical language may have developed close to 100 Kya, corresponding with a punctuated (as opposed to gradual) increase in brain size and near the emergence of a fifth order of intentionality in the hominin record (Fig. 17.1).

There have, of course, been criticisms of the Social Brain Hypothesis (e.g., Barrett, Henzi, & Rendall, 2007; de Ruiter, Weston, & Lyon, 2011) and the application of orders of intentionality to the hominin behavioral record. Dunbar (2007) himself argues that there is no real need for the Social Brain Hypothesis to correspond to the archaeological record, as only limited insight is gained from behavioral evidence. The Social Brain Hypothesis explicitly deals with the mental processes underlying social behavior, rather than overt behavior or aspects of cognition that focus on instrumental skills like tool-making. Tools, in effect, become a red herring, as the mindsets that lie at the core of the Social Brain Hypothesis are unlikely to leave a visible trace in the fossil record that archaeologists may relate to tools (Dunbar, 2007). Therefore, assigning orders of intentionality to the hominin fossil record based on brain size holds true as an estimate of cognitive ability.

However, extensive archaeological studies have identified material culture as an active participant in maintaining and structuring social relations (Barham, 2010; Gamble, 1999, 2007; Gosden & Marshall, 1999; Ingold, 2007). These results are supported by ethnographic studies that illustrate tools mediate social relations, beliefs, and social practices (Killick, 2004). Even if it is often unclear which hominin species definitively produced which different tool types, tool-making and material culture creation are intrinsically social and cognitive acts related to problem-solving and learning, however they were achieved (e.g., through imitation, observation, or demonstration) (Bamforth & Finlay, 2008; Barham, 2010; Stout et al., 2002; Stout & Chaminade, 2012). Therefore, tools have great potential to provide insight into the behavioral and achieved cognitive complexities of their hominin creators.

Stone Tools and Orders of Intentionality

Anthropogenically modified stone artifacts from the Paleolithic encompass a number of lithic technologies, geographical regions, and descriptive terminologies. The technological variability is unsurprising, given the span of more than 3.3 million years. Diverse approaches to this technological variability have emphasized its different aspects, including flake production, typological form, metrical variation, core reduction, and microwear analysis (Foley & Lahr, 2003; Gowlett, 2009).

Clark's (1961) technological modes (Fig. 17.1; Table 17.1) have provided a usefully broad comparative scale, if one that perhaps lacks the fine granularity needed to tackle the versatility of hominin behavior. Although there are valid issues with Clark's modes and their application by archaeologists to the Paleolithic record (Bar-Yosef & Belfer-Cohen, 2001), the technological modes do provide a useful framework for comparing data throughout the span of time (Gamble, 2013), though they tend to ignore the often more nuanced local or regional records and raw material availability. The modes also allow for broad comparisons of lithic technology that sidestep the rigid homotaxial sequence adopted by many researchers, and they take into account the continuities between technologies and time divisions. Such a big-picture approach is needed to deal with the equally big picture of hominin cognitive abilities, where the modes reflect a broad trajectory of increasing technological complexity, greater control of knapping techniques, and raw material utilization (Foley & Lahr, 2003). Although the use of modes is by no means ideal, they do serve as a useful heuristic for the purposes of this discussion. Future work will focus on producing a cognitive model that incorporates the local small-scale complexities and variability within the broad designations of hominin cognition.

I have previously used the modes of technology in conjunction with the Identity Model to relate the orders of intentionality to the archaeological record based on the minimum levels of cognitive complexity required to incorporate material culture into active social signaling at the individual and group levels (Cole, 2017). The relationships for the modes of technology, their behavioral implications, and orders of intentionality under the Identity Model schema are summarized in Table 17.2.

[Table 17.2]

Here it is important to note that although the boundaries between material culture categories are based on Clark's technological modes, in reality we know that the archaeological record, hominin behavior, and hominin cognition are rarely (if ever) so neat and tidy. Therefore, the application of the orders of intentionality to the archaeological record should focus on derived (or developed) artifacts and what they imply for hominin cognition. Fig. 17.1 highlights the fact that, even within the same species, brain size varies, and so too would the order of intentionality according to the assignments under the Social Brain Hypothesis. It is strongly advocated here that we seek to acknowledge the complexity of the behavioral record and apply the same reasoning: Perhaps different cultural groups within the same species attained different orders of intentionality and expressed them differently in their behavioral record. Therefore, if a derived element from a higher category of material culture (focus here on the material culture description column in Table 17.2, rather than the more familiar modes) is securely provenanced within an assemblage, then it may be cautiously inferred that the creating hominins may have attained the higher order of intentionality. For example, if a predominantly mode 3 lithic assemblage (generally third-to-fourth-order intentionality) contains an element of ornamentation such as beads (fifth-order intentionality), then that group (perhaps only at a local level) may have actively breached the fifth-order intentionality barrier. This in turn would suggest that the rest of the species may have had the potential to do the same within the variable-equilibrium framework. Indeed, much of our difficulty in modeling the cognitive abilities of our hominin ancestors comes from the fact that we tend to approach this at a broad species level, ignoring the nuanced potential for within-species cognitive variation as expressed through cultural variation in the artifactual record. Further difficulties lie in a general lack of understanding of population size and networks within and between Paleolithic hominin groups (discussed further below).

When Fig. 17.1 and Tables 17.1 and 17.2 are compared, there is an apparent mismatch in the order of intentionality assigned to the species and associated behavioral record. Perhaps the biggest difference is the suggestion that a second order of intentionality is only breached by those hominins producing mode 2 bifaces, starting with *H. ergaster* and *H. erectus*, rather than early *Homo* or the Paranthropines. It has been proposed elsewhere (Cole, 2015c, 2017; McNabb & Cole, 2015) that these differences can be partially explained by differences in biological change (e.g., brain size increases, which must come first) vs. behavioral change (which follows). The Social Brain predictions for hominin intentionality based on brain size are therefore a good measure of maximum hominin cognitive *potential*, whereas the order of intentionality as seen through the archaeological record and the Identity Model illustrate the *realized* cognitive level. In reality, hominins may well have lived somewhere between the two prediction ranges, much the same way modern humans fluctuate between fifth- and sixth-order intentionality and great apes fluctuate between first- and second-order intentionality.

The key component for Table 17.2 vs. Fig. 17.1 and Table 17.1 is the suggestion that the biface makers of Acheulean (or mode 2) artifacts are firmly grounded within a consciously realized second order of intentionality or a theory of mind. The reasoning is explained in more detail in McNabb and Cole (2015) but centers on the notion that mode 2 bifaces share a conceptual standardization (McNabb, Binyon, & Hazelwood, 2004), even though the exact final form remains a fluid concept, allowing its adaptation to raw material quality, knapper skill, and desired function and aesthetic. In order to make a mode 2 biface, a knapper would have needed to hold an abstract concept of the handaxe in their mind’s eye (Ashton & McNabb, 1994) before the manufacture process could proceed. That is, randomly bashing a nodule will not produce a mode 2 biface (but see McPherron, 2000). This implies that in order to knap a handaxe, the knapper must have had the ability for abstract thought—to conceive of the artifact and knapping strategy before removing the first flake from the nodule. A theory of mind, in turn, is an example of abstract thought. Hominins learned how to make handaxes by recognizing the intention of others’ handaxes within a social and cultural framework that influenced their own knapping. The act of handaxe making in a social context therefore implies and requires a theory of mind (McNabb & Cole, 2015).

Mode 2 biface manufacture does not, however, require a third order of intentionality. What does require third-order intentionality is the creation of composite tools (mode 3) and the use of material culture as an active agent in mediating social relationships and creating symbols, although this also fits well within a fourth-order bracket, and a language system grounded in visual display and complex gestures (Cole, 2017). It is not until a fifth order of intentionality that we would expect to see a full-blown ability for grammatical language and the creation of material culture (e.g., beads, art, and figurines) representing a complex imaginary mythology that can only be explained through spoken language (Cole, 2017).

As mentioned above, the archaeological record rarely (if ever) fits into such neat categories, however much modern researchers would like it to. Sites often suggest that hominins may have been operating at a higher (or lower) cognitive level than would generally be predicted. Surprising findings include Neandertal symbolism and jewelry (Radovčić et al., 2015; Welker et al., 2016; Zilhão et al., 2010) and giant handaxes, s-twists, and pairs perhaps used as vehicles for social signaling in the Lower Paleolithic (Hopkinson & White, 2005; Pope, Russel, & Watson, 2006; Wenban-Smith, 2004; White, 1998; White & Plunkett, 2004). The explanatory link here between expected level of cognition and behavioral output is the variable-equilibrium between the maximum cognitive potential of species (as predicted by the Social Brain Hypothesis; see Fig. 17.1) and the obtained behavioral threshold (as summarized in Fig. 17.2 and Table 17.2). The variable-equilibria of species cognition within a staircase framework of punctuated increasing brain size (Shultz et al., 2012) means that if social and environmental conditions allow, then individual communities may break through their previously realized behavioral threshold and engage in behaviors that match a higher level of cognitive potential. Within the Lower Paleolithic, the archaeological patterning suggests that small, isolated populations were occasionally able to innovate beyond the broader species cognitive level and engage with material culture production at social and symbolic levels associated with higher orders of intentionality. These innovations do not often feed into the broader species level, since small, isolated populations by definition are associated with poor or limited social networks between groups, which inhibits cultural and cognitive transmission to the wider population (Cole, 2015a, 2017).

[Figure 17.2]

Therefore, when we examine the archaeological record, we must take into account the full range of complexity present between the cognitive potential of a species, their normal expected behavioral output, and those moments when groups or communities extend themselves to their full cognitive and behavioral potential within the context of population dynamics and social networks. We must take not only a broad-brush approach to understanding the past, but also drill down to site-specific details, in order to populate the canvas with details. Fortunately, Wynn has long been a proponent of such an approach (Wynn, 2002, 2009; Wynn & Coolidge, 2004; Wynn, Hernandez-Aguilar, Marchant, & McGrew, 2011), and we should endeavor to incorporate such detail in our analyses. To ignore this degree of complexity and attempt to reduce behavioral and cognitive complexity to a general species level means that we will never be able to identify the sparks that drove the cognitive steps between each order of intentionality.

Conclusion

This paper has explored the relationships between a theory of mind, orders of intentionality, and the Paleolithic record. Such a correlation has highlighted the disparities between cognitive predictions based on brain size, such as the Social Brain Hypothesis, and those based on examining archaeological artifacts viewed as the behavioral results of cognitive processes. This disconnect, however, is not necessarily the result of incompatible methods of analysis or the inability of modern researchers to access the minds of our hominin ancestors. Rather, the differences may more truly represent hominin behavior and cognition. Modern humans have a range of complex behaviors and cognitive states that cannot be applied universally across our species, and it is perhaps therefore unfair for us to assume that we are the only human species to have such variability. If we embrace the complexity of the archaeological and fossil records and view them through the lens of the variable-equilibria model, we can begin to see that the variability within species at the individual and group levels produces a richer interpretation of the past than has previously been attained.

This holistic interpretation of varied hominin inter- and intra-species complexity may be supported by recent Paleogenetic evidence suggesting that *H. sapiens* is a mosaic species, incorporating genetic inputs from several archaic hominin species. It is not unreasonable to assume, therefore, that the hominin species we interacted with (e.g., the Neandertals and

Denisovans) may have been more like us than we have previously thought and acknowledged. Indeed, the Neandertals and Denisovans must have been recognizably human, not only in a biological sense, but behaviorally as well. This would include complex stone tools and organic technologies, complex language systems, and symbolic material culture. Otherwise, we must question what drove the desire to interbreed (even if it was only at a limited scale?); after all, practically and figuratively speaking, you can't start a fire without a spark.

No doubt, future discoveries regarding human species and the origins of lithic technology will change the boundaries proposed here for relating the archaeological record to orders of intentionality. However, we should embrace these changes and welcome the increasing degrees of complexity such discoveries suggest. After nearly 150 years of studying the Paleolithic, we are entering an era of unprecedented methodological rigor and scientific study, still just barely scratching the surface of what it means to be human and understanding our hominin ancestors.

Acknowledgments

I would like to thank a number of colleagues for their input through various discussions on this topic, including John McNabb, Clive Gamble, John Gowlett, and Robin Dunbar. In addition, the reviewers' comments for this paper were also extremely helpful and supportive; any remaining errors are my own. I would also like to thank Tom, Fred, and Leee for the invitation to contribute to this volume. I will always be thankful for the many conversations I have had with Tom regarding handaxes and hominin cognition; they were not only highly informative but also extremely enjoyable. Tom has certainly defined the discipline of cognitive archaeology and inspired many of us to follow in his footsteps.

References

Aiello, L. C., & Dunbar, R. I. M. (1993). Neocortex size, group size and the evolution of language. *Current Anthropology, 34*(2), 184–193.

Ashton, N. M., & McNabb, J. (1994). Bifaces in perspective. In N. Ashton & A. David (Eds.), *Stories in stone: Proceedings of the anniversary conference at St. Hilda's College Oxford, April 1994* (pp. 182–191). London: Lithic Studies Society.

Bamforth, D. B., & Finlay, N. (2008). Introduction: Archaeological approaches to lithic production skill and craft learning. *Journal of Archaeological Method and Theory, 15*(1), 1–27.

Bar-Yosef, O., & Belfer-Cohen, A. (2001). From Africa to Eurasia: Early dispersals. *Quaternary International*, *75*(1), 19–28.

Barbieri, M. (2010). On the origin of language: A bridge between biolinguistics and biosemiotics. *Biosemiotics*, *3*(2), 201–223.

Barham, L. S. (2010). A technological fix for Dunbar's dilemma? In R. I. M. Dunbar, C. Gamble, & J. A. J. Gowlett (Eds.), *Social brain, distributed mind* (pp. 367–389). London: British Academy.

Baron-Cohen, S. (2001). Theory of mind in normal development and autism. *Prisme*, *34*(1), 174–183.

Barrett, L., Henzi, P., & Rendall, D. (2007). Social brains, simple minds: Does social complexity really require cognitive complexity? *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *362*(1480), 561–575.

Berger, L. R., Hawks, J., De Ruiter, D. J., Churchill, S. E., Schmid, P., Delezene, L. K., … Zipfel, B. (2015). *Homo naledi*, a new species of the genus *Homo* from the Dinaledi Chamber, South Africa. *Elife, 4*, 1–35.

Brown, P., Sutikna, T., Morwood, M. J., Soejono, R. P., Saptomo, E. W., & Due, R. A. (2004). A new small-bodied hominin from the Late Pleistocene of Flores, Indonesia. *Nature*, *431*(7012), 1055–1061.

Call, J., & Tomasello, M. (2008). Does the chimpanzee have a theory of mind? 30 years later. *Trends in Cognitive Sciences*, *12*(5), 187–192.

Cheney, D. L., & Seyfarth, R. M. (1990). *How monkeys see the world: Inside the mind of another species*. Chicago, IL: University of Chicago Press.

Clark, G. (1961). *World prehistory: In new perspective*. Cambridge: Cambridge University Press.

Cole, J. (2012). The Identity Model: A method to access visual display and hominin cognition within the Palaeolithic. *Human Origins*, *1*, 24–40.

Cole, J. (2015a). Examining the presence of symmetry within Acheulean handaxes: A case study in the British Palaeolithic. *Cambridge Archaeological Journal*, *24*(4), 713–732.

Cole, J. (2015b). Handaxe symmetry in the Lower and Middle Palaeolithic: Implications for the Acheulean gaze. In F. Coward, R. Hosfield, M. I. Pope, & F. Wenban-Smith (Eds.), *Settlement, society and cognition in human evolution: Landscapes in mind* (pp. 234–257). Cambridge: Cambridge University Press.

Cole, J. (2015c). Hominin language development: A new method of archaeological assessment. *Biosemiotics*, *8*(1), 67–90.

Cole, J. (2017). Accessing hominin cognition: Language and social signalling in the Lower to Middle Paleolithic. In T. Wynn & F. L. Coolidge (Eds.), *Cognitive models in Palaeolithic archaeology* (pp. 157–195). New York: Oxford University Press.

Crockford, C., Wittig, R. M., Mundry, R., & Zuberbühler, K. (2012). Wild chimpanzees inform ignorant group members of danger. *Current Biology*, *22*(2), 142–146.

D'Errico, F., Henshilwood, C. S., Lawson, G., Vanhaeren, M., Tillier, A.-M., Soressi, M., … Julien, M. (2003). Archaeological evidence for the emergence of language, symbolism, and music—An alternative multidisciplinary perspective. *Journal of World Prehistory*, *17*(1), 1–70.

D'Errico, F., Henshilwood, C. S., Vanhaeren, M., & Van Niekerk, K. L. (2005). *Nassarius kraussianus* shell beads from Blombos Cave: Evidence for symbolic behaviour in the Middle Stone Age. *Journal of Human Evolution*, *48*(1), 3–24.

Davidson, I., & Noble, W. (1989). The archaeology of perception: Traces of depiction and language. *Current Anthropology, 30*(2), 125–155.

Davidson, I., & Noble, W. (1993). Tools and language in human evolution. In K. R. Gibson & T. Ingold (Eds.), *Tools, language and cognition in human evolution* (pp. 363–388). Cambridge: Cambridge University Press.

Deacon, T. W. (1997). *The symbolic species: The co-evolution of language and the brain*. New York: W.W. Norton & Co.

De Ruiter, J., Weston, G., & Lyon, S. M. (2011). Dunbar's number: Group size and brain physiology in humans reexamined. *American Anthropologist*, *113*(4), 557–568.

De Veer, M. W., & Van den Bos, R. (1999). A critical review of methodology and interpretation of mirror self-recognition research in nonhuman primates. *Animal Behaviour*, *58*(3), 459–468.

Dennell, R. W. (2004). Hominid dispersals and Asian biogeography during the Lower and Early Middle Pleistocene, c. 2.0–0.5 Mya. *Asian Perspectives*, *43*(2), 205–226.

Dirks, P. H. G. M., Roberts, E. M., Hilbert-Wolf, H., Kramers, J. D., Hawks, J., Dosseto, A., … Berger, L. R. (2017). The age of Homo naledi and associated sediments in the Rising Star Cave, South Africa. *eLife*, *6*, e24231.

Dunbar, R. I. M. (1992). Neocortex size as a constraint on group size in primates. *Journal of Human Evolution*, *22*(6), 469–493.

Dunbar, R. I. M. (1996). *Grooming, gossip and the evolution of language*. London: Faber and Faber.

Dunbar, R. I. M. (1998a). The social brain hypothesis. *Evolutionary Anthropology: Issues, News, and Reviews*, *6*(5), 178–190.

Dunbar, R. I. M. (1998b). Theory of mind and the evolution of language. In J. R. Hurford, M. Studdert-Kennedy, & C. Knight (Eds.), *Approaches to the evolution of language* (pp. 92–110). Cambridge: Cambridge University Press.

Dunbar, R. I. M. (2003). The social brain: Mind, language, and society in evolutionary perspective. *Annual Review of Anthropology*, *32*(1), 163–181.

Dunbar, R. I. M. (2004). *The human story: A new history of mankind's evolution*. London: Faber and Faber.

Dunbar, R. I. M. (2007). The social brain and the cultural explosion of the human revolution. In P. Mellars, K. Boyle, O. Bar-Yosef, & C. Stringer (Eds.), *Rethinking the human revolution: New behavioural and biological perspectives on the origin and dispersal of modern humans* (pp. 91–98). Cambridge: McDonald Institute for Archaeological Research.

Dunbar, R. I. M., Gamble, C., & Gowlett, J. A. J. (Eds.). (2010). *Social brain, distributed mind*. London: British Academy.

Dunbar, R. I. M., Gamble, C., & Gowlett, J. A. J. (Eds.). (2014). *Lucy to language: The benchmark papers*. Oxford: Oxford University Press.

Dunbar, R. I. M., & Shultz, S. (2007). Evolution in the social brain. *Science*, *317*(5843), 1344–1347.

Foley, R. A., & Lahr, M. M. (2003). On stony ground: Lithic technology, human evolution and the emergence of culture. *Evolutionary Anthropology: Issues, News, and Reviews*, *12*(3), 10–122.

Gamble, C. (1999). *The Palaeolithic societies of Europe*. Cambridge, MA: Cambridge University Press.

Gamble, C. (2007). *Origins and revolutions: Human identity in earliest prehistory*. Cambridge: Cambridge University Press.

Gamble, C. (2012). When the words dry up: Music and material metaphors half a million years ago. In N. Bannan (Ed.), *Music, language, and human evolution* (pp. 81–106).

Oxford: Oxford University Press.

Gamble, C. (2013). *Settling the earth: The archaeology of deep human history*. New York: Cambridge University Press.

Gamble, C., Gowlett, J. A. J., & Dunbar, R. I. M. (2014). *Thinking big: How the evolution of social life shaped the human mind*. London: Thames & Hudson.

Gosden, C., & Marshall, Y. (1999). The cultural biography of objects. *World Archaeology*, *31*(2), 169–178.

Gowlett, J. A. J. (1979). Complexities of cultural evidence in the Lower and Middle Pleistocene. *Nature*, *278*(5699), 14–17.

Gowlett, J. A. J. (1996). Mental abilities of early *Homo*: Elements of constrain and choice in rule systems. In P. Mellars & K. R. Gibson (Eds.), *Modelling the early human mind* (pp. 191–215). Oxford: Oxbow Books.

Gowlett, J. A. J. (2009). The longest transition or multiple revolutions? Curves and steps in the record of human origin. In M. Camps & P. R. Chauhan (Eds.), *Sourcebook of Paleolithic transitions: Methods, theories and interpretations* (pp. 65–78). Berlin: Springer Verlag.

Gowlett, J. A. J., Gamble, C., & Dunbar, R. I. M. (2012). Human evolution and the archaeology of the social brain. *Current Anthropology*, *53*(6), 693–722.

Harmand, S., Lewis, J. E., Feibel, C. S., Lepre, C. J., Prat, S., Lenoble, A., … Roche, H. (2015). 3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya. *Nature*, *521*(7552), 310–315.

Hopkinson, T., & White, M. J. (2005). The Acheulean and the handaxe: Structure and agency in the Palaeolithic. In C. Gamble & M. Porr (Eds.), *The hominid individual in context: Archaeological investigations of Lower and Middle Palaeolithic landscapes, locales and artefacts* (pp. 13–28). London: Routledge.

Ingold, T. (2007). Materials against materiality. *Archaeological Dialogues*, *14*(1), 1–16.

Joordens, J. C. A., D'Errico, F., Wesselingh, F. P., Munro, S., De Vos, J., Wallinga, J., … Roebroeks, W. (2015). *Homo erectus* at Trinil on Java used shells for tool production and engraving. *Nature*, *518*(7538), 228–231.

Killick, D. (2004). Social constructionist approaches to the study of technology. *World Archaeology*, *36*(4), 571–578.

Krupenye, C., Kano, F., Hirata, S., Call, J., & Tomasello, M. (2016). Great apes anticipate that other individuals will act according to false beliefs. *Science, 354*(6308), 110–114.

Lycett, S. J., & Norton, C. J. (2010). A demographic model for Palaeolithic technological evolution: The case of East Asia and the Movius Line. *Quaternary International*, *211*(1), 55–65.

McNabb, J. (2012). The importance of conveying visual information in Acheulean society: The background to the visual display hypothesis. *Human Origins*, *1*, 1–23.

McNabb, J., Binyon, F., & Hazelwood, L. (2004). The large cutting tools from the South African Acheulean and the question of social traditions. *Current Anthropology*, *45*(5), 653–677.

McNabb, J., & Cole, J. (2015). The mirror cracked: Symmetry and refinement in the Acheulean handaxe. *Journal of Archaeological Science: Reports*, *3*, 100–111.

McPherron, S. P. (2000). Handaxes as a measure of the mental capabilities of early hominids. *Journal of Archaeological Science*, *27*(8), 655–663.

Meyer, M., Arsuaga, J. L., Filippo, C. de, Nagel, S., Aximu-Petri, A., Nickel, B., … Pääbo, S. (2016). Nuclear DNA sequences from the Middle Pleistocene Sima de los Huesos hominins. *Nature*, *531*(7595), 504–507.

Meyer, M., Arsuaga, J. L., Nagel, S., Martínez, I., Gracia, A., De Castro, J. M. B., … Pääbo, S. (2015). Nuclear DNA sequences from the hominin remains of Sima de los Huesos, Atapuerca, Spain. In *Proceedings of the European Society for the study of Human Evolution* (Vol. 4, p. 162).

Nielsen, M., & Dissanayake, C. (2004). Pretend play, mirror self-recognition and imitation: A longitudinal investigation through the second year. *Infant Behavior and Development*, *27*(3), 342–365.

Origgi, G., & Sperber, D. (2000). Evolution, communication and the proper function of language. In P. Carruthers & A. Chamberlain (Eds.), *Evolution and the human mind: Modularity, language and meta-cognition* (pp. 140–169). Cambridge: Cambridge University Press.

Peirce, C. S. (1974). Basis of pragmatism. In C. Hartshorne & P. Weiss (Eds.), *The collected papers of Charles Sanders Peirce* (Vol. 1, pp. 1931–1935). Cambridge, MA: Harvard University Press.

Plotnik, J. M., De Waal, F. B. M., & Reiss, D. (2006). Self-recognition in an Asian elephant. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(45), 17053–17057.

Pope, M. I., Russel, K., & Watson, K. (2006). Biface form and structured behaviour in the Acheulean. *Lithics: The Journal of the Lithic Studies Society*, *27*, 44–57.

Povinelli, D. J., Gallup, G. G., Eddy, T. J., Bierschwale, D. T., Engstrom, M. C., Perilloux, H. K., & Toxopeus, I. B. (1997). Chimpanzees recognize themselves in mirrors. *Animal Behaviour*, *53*(5), 1083–1088.

Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, *4*, 515–526.

Proffitt, T., Luncz, L. V, Falótico, T., Ottoni, E. B., De la Torre, I., & Haslam, M. (2016). Wild monkeys flake stone tools. *Nature*, *539*(7627), 85–88.

Radovčić, D., Sršen, A. O., Radovčić, J., & Frayer, D. W. (2015). Evidence for Neandertal jewelry: Modified white-tailed eagle claws at Krapina. *PLoS One*, *10*(3), 1–14.

Reiss, D., & Marino, L. (2001). Mirror self-recognition in the bottlenose dolphin: A case of cognitive convergence. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(10), 5937–5942.

Savanah, S. (2013). Mirror self-recognition and symbol-mindedness. *Biology and Philosophy*, *28*(4), 657–673.

Seyfarth, R. M., & Cheney, D. L. (2011). Animal cognition: Chimpanzee alarm calls depend on what other know. *Current Biology*, *22*(2), R51–R52.

Seyfarth, R. M., & Cheney, D. L. (2013). Social cognition: The primate mind before tools, language, and culture. In G. Hatfield & H. Pittman (Eds.), *Evolution of mind, brain, and culture* (pp. 105–122). Philadelphia: University of Pennsylvania Press.

Seyfarth, R. M., & Cheney, D. L. (2017a). Precursors to language: Social cognition and pragmatic inference in primates. *Psychonomic Bulletin & Review*, *24*(1), 79–84.

Seyfarth, R. M., & Cheney, D. L. (2017b). The origin of meaning in animal signals. *Animal Behaviour*, *124*, 339–346.

Shultz, S., Nelson, E., & Dunbar, R. I. M. (2012). Hominin cognitive evolution: Identifying patterns and processes in the fossil and archaeological record. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *367*(1599), 2130–2140.

Stout, D. (2011). Stone toolmaking and the evolution of human culture and cognition. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *366*(1567), 1050–1059.

Stout, D., Bril, B., Roux, V., De Beaune, S. A., Gowlett, J. A. J., Keller, C. M., … Stout, D. (2002). Skill and cognition in stone tool production: An ethnographic case study from Irian Jaya 1. *Current Anthropology*, *43*(5), 693–722.

Stout, D., & Chaminade, T. (2012). Stone tools, language and the brain in human evolution. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *367*(1585), 75–87.

Stout, D., Hecht, E. E., Khreisheh, N., Bradley, B. A., & Chaminade, T. (2015). Cognitive demands of Lower Paleolithic toolmaking. *PLoS One*, *10*(4), 1–18.

Thieme, H. (1997). Lower Palaeolithic hunting spears from Germany. *Nature*, *385*(6619), 807–810.

Van der Vaart, E., & Hemelrijk, C. K. (2012). “Theory of mind” in animals: Ways to make progress. *Synthese*, *191*(3), 335–354.

Van Schaik, C. P. (2013). The costs and benefits of flexibility as an expression of behavioural plasticity: A primate perspective. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *368*(1618), 1–9.

Vanhaeren, M., D’Errico, F., Stringer, C., James, S. L., Todd, J. A., & Mienis, H. K. (2006). Middle Paleolithic shell beads in Israel and Algeria. *Science*, *312*(5781), 1785–1788.

Warren, S. H. (1911). On a Palaeolithic (?) wooden spear. *Quarterly Journal of the Geological Society of London*, *67*, xcix.

Watts, I., Chazan, M., & Wilkins, J. (2016). Early evidence for brilliant ritualized display: Specularite use in the Northern Cape (South Africa) between∼500 and∼300 Ka. *Current Anthropology*, *57*(3), 287–310.

Welker, F., Hajdinjak, M., Talamo, S., Jaouen, K., Dannemann, M., David, F., … Hublin, J.-J. (2016). Palaeoproteomic evidence identifies archaic hominins associated with the Châtelperronian at the Grotte du Renne. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(40), 11162–11167.

Wenban-Smith, F. (2004). Handaxe typology and Lower Paleolithic cultural development: Ficrons, cleavers and two giant handaxes from Cuxton. *Lithics: The Journal of the Lithic Studies Society*, *25*, 11–21.

White, M. J. (1998). Twisted ovate bifaces in the British Lower Palaeolithic: Some observations and implications. In N. Ashton, F. Healy, & P. Pettitt (Eds.), *Stone Age archaeology: Essays in honour of John Wymer* (Vol. 6, pp. 98–104). Oxford: Lithic Studies Society.

White, M. J., & Plunkett, S. J. (2004). *Miss Layard excavates: A Palaeolithic site at Foxhall Road, Ipswich, 1903–1905*. Liverpool: Western Academic & Specialist Press.

Wynn, T. (1979). The intelligence of later Acheulean hominids. *Man*, *14*, 371–391.

Wynn, T. (1981). The intelligence of Oldowan hominids. *Journal of Human Evolution*, *10*(7), 529–541.

Wynn, T. (1985). Piaget, stone tools and the evolution of human intelligence. *World Archaeology*, *17*(1), 32–43.

Wynn, T. (1991). Tools, grammar and the archaeology of cognition. *Cambridge Archaeological Journal*, *1*(2), 191–206.

Wynn, T. (1995). Handaxe enigmas. *World Archaeology*, *27*(1), 10–24.

Wynn, T. (2002). Archaeology and cognitive evolution. *Behavioral and Brain Sciences*, *25*(3), 389–402.

Wynn, T. (2009). Hafted spears and the archaeology of mind. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(24), 9544–9545.

Wynn, T., & Coolidge, F. L. (2004). The expert Neandertal mind. *Journal of Human Evolution*, *46*(4), 467–487.

Wynn, T., & Coolidge, F. L. (Eds.). (2017). *Cognitive models in Palaeolithic archaeology*. New York: Oxford University Press.

Wynn, T., Hernandez-Aguilar, R. A., Marchant, L. F., & McGrew, W. C. (2011). "An ape's view of the Oldowan" revisited. *Evolutionary Anthropology*, *20*(5), 181–197.

Zilhão, J., Angelucci, D. E., Badal-García, E., d'Errico, F., Daniel, F., Dayet, L., … Zapata, J. (2010). Symbolic use of marine shells and mineral pigments by Iberian Neandertals. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(3), 1023–1028.

Table 17.1. Orders of Intentionality, Hominins Species, and Technological Modes.

Order of Intentionality	Achieved By	Hominin Species	Technological Mode
Fifth	Modern humans with language as we know it	*H. sapiens*, some *H. neanderthalensis* (?)	Mode 4—prepared core technology (blades)
Fourth	Last common ancestor with/ and Neandertals	*H. heidelbergensis*, *H. neanderthalensis*	Some mode 2—bifacial handaxes, mostly mode 3—prepared core technology (flakes)
Third	All large-brained hominins (> 900 cc)	*H. ergaster*, *H. erectus*, *H. antecessor*, some *H. heidelbergensis*	Some mode 1—simple flake and core, mostly mode 2—bifacial handaxes
Second (Theory of Mind)	5-year-old children (*H. sapiens*), all small brained hominins (400–900 cc), and possibly great apes	*A. afarensis*, *A. africanus*, *A. garhi*, *A. sediba*, *P. boisei*, *P. robustus*, *P. aethiopicus*, *H. rudolfensis*, *H. naledi*, *H. habilis*, some *H. ergaster*, some *H. erectus*	Lomekwian and mode 1—simple flake and core, some mode 2—bifacial handaxes
First	Monkeys, lesser apes, and some mammals such as elephants and dolphins, small brained hominins (< 400 cc)	*A. ramidus*, some *A. afarensis*	Unknown, but perhaps similar to flakes produced by capuchins (cf. Proffitt et al., 2016)

Note: Adapted from Table 5.2 (p. 146) in Gamble et al. (2014), *Thinking big: How the evolution of social life shaped the human mind*, Thames & Hudson; also see Box 2.3 (pp. 64–65) in Gamble (2013), *Settling the earth: The archaeology of deep human history*, Cambridge University Press; Clark (1961), *World prehistory: In new perspective*, Cambridge University Press; and Fig. 17.1.

Table 17.2. Relations between Technology, Behaviors, and Orders of Intentionality.

Technological Mode	Material Culture Description	Behavioral Implication	Order of Intentionality
1 (Early Stone Age / Lower Paleolithic: includes the Lomekwian in this schema) ca. 3.3 Mya to ca. < 10 Ka	• Deliberate lithic tool production to create edges for use • No standard form imposition; tool shape largely governed by raw material size, shape, and mechanical flaking properties • Consists of pebble tool industries dominated by small flake removals (< 10 cm) and chopping tools (Oldowan), or large flake removals (Lomekwian) • Possible bone or wood tools that have limited evidence for anthropogenic modification	• Hominins have a realized sense of self that compliments the egocentric, goal-directed behavior reflected in the strategies of tool production. • Evidence for some forward planning in raw material procurement • Social communications governed by egocentric, dyadic, gestural, and attention-directed auditory signals with a presumably greater repertoire than extant primates • Imitative learning present	First-order
2 (Early Stone Age / Lower Paleolithic: Acheulean) ca. 1.7 Mya to ca. 100–60 Ka	• Lithic tools predominantly based on large flakes (> 10 cm) or bifacially reduced cores. • Consists mostly of bifacially knapped handaxes and cleavers (Large Cutting Tools, LCT), although flakes, flake tools, and cores still being produced • Regional variation in shape and form primarily affected by raw material. • Deliberate imposition of shape and form to LCTs evidenced through the presence of a mental construct in regards to LCT form with a degree of conceptual standardization; final LCT form remains a fluid concept with no evidence for an increase in artifact symmetry or	• Hominins have a consciously realized Theory of Mind that marks the beginning of abstract thought; this in turn is reflected in the imposition of deliberate shape and form on handaxes that can only have been knapped through the knapper having a mental construct (no matter how fluid) of the artifact before the process started. • Evidence for goal-directed behavior associated with greater planning capabilities and complex imitative and active social learning, organized hunting, and controlled use of fire. • Group organization reflecting complex social communications / language	Second-order (Theory of Mind)

	standardized form through time. • Organic artifacts may be in use (e.g., wooden spears for hunting).	grounded in visual display	
Toward the end of Mode 2 as the dominate technological expression ca. 400 Ka to 200 Ka	• Individual groups may produce artifacts of extraordinary design, such as giant handaxes, S-twist handaxes, handaxe pairs, symmetrical handaxes. • An element of prepared core technology (mode 3) may enter the behavioral record, although there is still a strong emphasis on large flake production and bifacially reduced cores.	• If assemblages have a definite bias toward “true” symmetry or contain artifacts of ‘extraordinary design’ (e.g., giant handaxes), then it may be that such artifacts have an implication beyond the purely functional and may hold some social or cultural significance. • If there is the presence of mode 3 and composite tools within mode 2 assemblages, then perhaps there is a more sustained cognitive break through beyond a Theory of Mind.	Second to third-order
3 (Prepared Core, Middle Stone Age / Middle Paleolithic: Levallois) ca. 300 Ka to ca. < 40 Ka	• A shift from producing lithic tools from cores and flakes to preparing cores to extract flakes of a particular form and size • Prepared core technology (e.g., Levallois) focuses on producing standardized flakes with the potential for later modification (e.g., into points or handaxes). • This type of lithic production also indicates the presence of composite tools. • Regional variation possibly driven by cultural influences rather than raw material, although raw material may still govern shape and size of artifact to a certain degree • Use of organic material culture for composite tool creation • Use of ochre evident	• Hominins have a commonality of understanding (cultural affinities) and a clear sense of shape and form that begin to play a role beyond the purely functional. • The capability to produce composite tools displays an ability for abstract thought beyond a functional level, which may manifest itself in the beginnings of cultural signaling seen within the archaeological record, such as the use of pigments. • Artifacts maintain a predominantly functional significance but may carry social meaning in regards to the creator or group. • Social communication is centered around complex gesture and utterance incorporated within visual	Third to fourth-order

		display.	
4 (Later Stone Age / Upper Paleolithic Blade and bladelet dominated assemblages e.g., Aurignacian) ca. 120 Ka to ca. < 10 Ka	• Continued emphasis on flake production with a predetermined shape and form • Flake blanks within this category are primarily concerned with composite tool production with limited secondary shaping. • Use of organic material culture for composite tool creation. This category includes an expanded repertoire of complex organic tools (such as harpoon heads). • In addition, material culture with a purely non-utilitarian design enters the record in the form of ornamentation (beads), art (cave and portable), and figurines (animal, humanoid, and anthropomorphic). • Clear evidence for regional variation in material culture production on a cultural basis	• Hominins have a commonality of understanding, a clear sense of shape and form, and the capacity for fully symbolic and functional abstract thought evidenced through the presence of non-utilitarian and composite material culture (decoration) and behaviors (e.g., symbolic burial). • Social communication is centered around visual display, gesture, and fully grammatical language. • Artifacts carry social meaning in relation to the creator and user (individual and group) and are now fully complicit in identity propagation of the individual and the group.	Fifth-order (occasionally sixth-order)

Note: Summary of how orders of intentionality map onto the archaeological record. Adapted from Table 8.4 (pp. 182–187) in Cole (2017), Accessing hominin cognition: Language and social signalling in the Lower to Middle Paleolithic, *Cognitive models in Palaeolithic archaeology*, Oxford University Press. Timing of technological modes adapted from Box 2.3 (pp. 64–65) in Gamble (2013), *Settling the earth: The archaeology of deep human history*, Cambridge University Press. The shades of grey correspond to those used in Fig. 17.1.

Figure 17.1. The fossil hominin timeline against hominin brain size, orders of intentionality, the first appearance datum (FAD), and last appearance datum (LAD) for the hominin behavioral record. The brown lines illustrate the punctuated changes in hominin brain size at 100 Kya, 400 Kya, 1 million years ago (Mya), and 1.8 Mya (Shultz, Nelson, & Dunbar, 2012). Cranial capacities and dates are from Shultz et al. (2012) and supplemented by additional information from Berger et al. (2015), Brown et al. (2004, and Dirks et al. (2017). The uncertainty surrounding the presence of *H. heidelbergensis* and the beginning of *H. neanderthalensis* reflect recent publications (e.g., Meyer et al., 2015, 2016); note the assignation of early *H. neanderthalensis* for the Atapuerca hominins (ca. 430 Kya) as a result. Orders of intentionality and their application to the fossil record after Dunbar (1992, 2004), Dunbar and Shultz (2007), and Gamble, Gowlett, and Dunbar (2014). Technological mode descriptions and dates adapted from Box 2.3 (pp. 64–65) in Gamble (2013), *Settling the earth: The archaeology of deep human history*, Cambridge University Press. Art and symbolism include beads, cave art, portable art, and the Trinil clam shell (Joordens et al., 2015). The extended use of ochre includes recent evidence from South Africa (Watts, Chazan, & Wilkins, 2016).

Figure 17.2. Schematic of the variable-equilibria model. The black dots indicate variability of brain size within species, not only between individuals but also within populations and groups. The species are suggested examples of those that have attained the corresponding orders of intentionality. However, the examples are not limited to those named. Adapted from Figs 5 and 6 (p. 109) in McNabb and Cole (2015), The mirror cracked: Symmetry and refinement in the Acheulean handaxe, *Journal of Archaeological Science: Reports*, *3*, 100–111 and republished with permission from Elsevier.