

How does thinking relate to tool making?

Lambros Malafouris

Adaptive Behavior
2021, Vol. 29(2) 107–121
© The Author(s) 2020



Article reuse guidelines:

sagepub.com/journals-permissions

DOI: 10.1177/1059712320950539

journals.sagepub.com/home/adb



Abstract

How the boundaries of the mind should be drawn with respect to action and the material world is a core research question that cognitive archaeology shares with contemporary cognitive sciences. The study of hominin technical thinking, as in the case of stone tool making, is a good way to bring that question to the fore. This article argues that archaeologists who study lithic artefacts and their transformations over the course of human evolution are uniquely well positioned to contribute to the ongoing debate about the marks of the mental. Adopting the material engagement approach, I propose to replace the internalist vision of mentality, that is, the vision of a brain-bound mind that is using the body to execute and externalise preconceived mental plan through the stone, with an ecological-enactive vision of participatory mentality where bodily acts and materials act together to generate rather than merely execute thought processes. I argue that the latter participatory view changes the geography of the cognitive and offers a better description for the continuity of mind and matter that we see in the lithic record.

Keywords

Cognitive archaeology, stone tool making, Material Engagement Theory, cognitive boundaries

Handling Editor: Karenleigh Anne Overmann

1. Introduction

What is the nature of the boundary between making and thinking? This article will attempt to explore that question by focusing on the skilled performance of a knapper detaching flakes from a flint core. I will be thinking primarily in terms of process and movement: for instance, the grip of the hand holding and lifting the hammerstone and striking the blank to produce a flake. How do the knapper's intention, perception and action relate? It is well documented, in experimental cognitive archaeology, that the knapping process requires smooth dexterous movements, fine manipulative abilities and eye–hand coordination. Different tools and materials will evoke different knapping techniques. There is a wide range of skills that need to be learned and practised in the relevant contexts of situated action. Still, within this broad spectrum of skill and expertise, the knapper must be able to sense the qualities of the stone, and predict the consequence of a strike given, as well as organise various functional parameters and gestural variables simultaneously (Chazan, 2015; Moore & Perston, 2016; Nonaka et al., 2010; Roux & Bril, 2005a, 2005b; Roux et al., 1995; Shea, 2015; Shipton et al., 2019; Stout et al., 2014; Hutchence &

Debackere, 2018). The skills and bodily techniques needed to control the shape of a flake take years of practice. Some of the 'design imperatives' (Wynn & Gowlett, 2018) and interactive parameters of the striking movement (e.g. kinetic energy/energetic efficiency, angle of blow and point of percussion) have been studied in detail for some time (Bril et al., 2010; Cueva-Temprana et al., 2019; Lycett & Eren, 2019; Mateos et al., 2019; Pargeter et al., 2019; Rein et al., 2014). What remains less understood, however, is the cognitive status of those shifting interactional dynamics connecting biomechanical features, anatomical constraints and skills. The crucial question about where do we draw the boundaries of the mind with respect to body, materials and techniques in the context of stone tool making has received little explicit attention in archaeology.

Institute of Archaeology, University of Oxford, Oxford, UK

Corresponding author:

Lambros Malafouris, Institute of Archaeology, University of Oxford, 36 Beaumont Str, OX1 2PG, Oxford, UK & Hertford College, OX1 3BW, Oxford, UK.

Email: lambros.malafouris@arch.ox.ac.uk

This is not surprising, considering that the nature of cognitive boundaries and the possible criteria for distinguishing non-cognitive processing from cognitive processing have been the subject of dispute in philosophy and cognitive science for too long. Presumably, archaeology has no epistemic obligation to contribute to this debate, not least to answer the ontological question about what constitutes cognition. Archaeologists, most researchers would agree, do not excavate minds, or cognitive processes, but rather, the material remains of past actions and behaviours. Moreover, current archaeological discourse is simply lacking the right kind of data and the theoretical expertise to critically engage and contribute to the debate over the so-called mark of the mental (Adams, 2010; Crane, 1998; Kirchhoff & Kiverstein, 2019; Rowlands, 2009). These may seem like fair points, but I suggest, that they misrepresent the current state and potential of archaeological thought. What is more important, they also create and reiterate some unintended pitfalls.

Here is the one I consider the most relevant to my purpose in this article: Instead of retaining an open, pluralistic and responsive stance on the hard problem of cognitive boundaries, archaeology seems to have adopted, from classical cognitive sciences, rather uncritically, a cognitivist or representational perspective to the fundamental question of what mind is and does. The distinctive characteristic of this cognitivist viewpoint is the separation between ‘inner’ brain processes and ‘outer’ bodily or material processes, and the concomitant assumption that the former, internal processes, are to be the natural measure of what counts as cognitive. Perhaps, adopting this dominant, orthodox view from cognitive science was natural during the formative period of cognitive archaeology. Nonetheless, this representational inheritance has prevented cognitive archaeology from developing its own distinctive perspective on the issue of cognitive boundaries, and thus, from making any original contribution to the cross-disciplinary dialogue over what makes something a cognitive process. Another major drawback of cognitivism, especially for lithic studies, was that major debates over the degree of cognitive complexity and variation associated with different early lithic technologies have been grounded on a series of ‘representational’ assumptions that a priori separate thought, perception and mediated action. In short, the study of stone tools seems to have uncritically accepted the modernist bifurcation of mind and matter disregarding the role that changing forms of materiality and situated action might have played in the constitution of cognitive processes, especially over longer time scales.

For sure, no one has ever denied that brain, bodies and tools interact. Human manual dexterity depends on both musculoskeletal and neurological capacities and constraints. The making and using of stone tools co-evolves with the anatomy and manipulative capabilities of the human hand (Bruner et al., 2018; Bruner & Iriki,

2016; Fedato et al., 2019; Key et al., 2018; Kivell, 2015). However, what I am questioning here is the representational stance most researchers tend to adopt in order to describe the nature of this interaction, as well as the temporal scale against which intelligence has predominantly been observed, or measured. This representational habit of seeing the mind as a brain-bound computational device is so deeply ingrained in archaeological discourse that it is hard for us to see how damaging the conceptual split between the mind and the material world has been. As a result, the cognitive status of stone tools remains unclear even for researchers influenced by Bernstein’s ideas on dexterity and Gibsonian ecological psychology who have long recognised, not always explicitly, that differentiations between ‘internal’ and ‘external’ are unhelpful when it comes to understanding tool-making activities and skills (e.g. Bril et al., 2015, 2010; Nonaka et al., 2010; Roux et al., 1995).

The major questions I want to ask in this article are the following: Where does the ‘thinking’ stop and the ‘flaking’ begin? Where do we draw the boundaries of the mind with respect to body, materials and techniques? The way we go about answering these questions, implicitly or explicitly, determines how we conceptualise both the nature of the relation and the direction of causality between mind stuff (cognitive, perceptual and affective processes) and material stuff (actions, bodies, materials, objects and environments). Can or should archaeology be concerned with those questions? This article will make the case that the study of lithic artefacts—their making and transformations—offers a unique perspective for approaching the ongoing debate about the marks of the cognitive. In particular, the main argument will be that the ordinary categorical distinctions between mind stuff and material stuff do not apply in the context of stone tool making. In this context, thought and action are one. Intention no longer comes before action but is *in the action*; the activity and the intentional state are now inseparable: At the cutting edge of a stone, the boundary between the mental and the physical collapses.

The argument is not that the process of tool making is boundless. Rather, what I will be arguing is that the boundary shiftings with the flow of action. Intention and material affordance become inseparable. From the perspective of stone tool making there can be no single answer to the question of where cognition begins and where it ends. I suggest that the case of stone tool making presents one of the earliest examples of *thinging*, that is, thinking *through, with and about* things. My specific claim is that the process of thinking *through* and *with* has a priority (developmental and evolutionary) over thinking *about* (Malafouris, 2013, 2016a, 2016b, 2019, 2020). The process of knapping should be understood on a par with the kind of situated intelligent processes referred to as embodied, embedded, enacted, or extended (known also as 4Es; Malafouris, 2018; Newen et al., 2018). These are processes distributed, both

spatially and temporally, over brain, body and world. In this sense, both ‘internal’ (inside the head) and ‘external’ (outside the head) elements of the knapping process should be accorded cognitive status.

My analysis follows, more specifically, the material engagement approach (Malafouris, 2010a, 2010b, 2013, 2014, 2015, 2019; Renfrew, 2004). I am proposing to replace the dominant internalist vision of *representational mentality* that uses the body to execute and externalise a preconceived mental plan through the stone, with an enactive and inherently dynamic vision of *participatory mentality* where bodily acts and material affordances generate and constitute thought processes rather than merely execute them. I will argue that adopting an enactivist material engagement perspective on tool making can help archaeology re-describe cognition in terms of mediated and situated action and to come up with new questions that will help us better understand the stone tools’ cognitive life. For instance, instead of thinking about tools as passive external objects that depend on human actions and thoughts, the material engagement approach allows us to conceptualise stone tools as active processes developmentally incorporated into our very own constitution as biological organisms and cognitive agents. Thus, we can think of tool making not just as the making of a tool by an animal body but also as the making of a body by the tool.

The French philosopher Bernard Stiegler, drawing on the work of paleoanthropologist André Leroi-Gourhan (1993), has been also viewing humanity as the product of technique, rather than the other way round, proposed the notion of ‘originary technicity’ to point out the inseparability of humans and techniques and the centrality of this process in human becoming (Stiegler, 1998). Similarly, many philosophers and cognitive scientists working within the post-phenomenological tradition of Don Ihde (Ihde, 1990; Ihde & Malafouris, 2019) or following recent ecological and enactive trends in embodied cognitive science (Chemero, 2009; Clark, 2008; Dreyfus, 2002; Gallagher, 2017; Hutto & Myin, 2017; Kirchhoff & Kiverstein, 2019; Newen et al., 2018; Rietveld & Kiverstein, 2014), reject the ontological splitting of the mental and physical components of action. The pioneer of cognitive anthropology, Gregory Bateson (1972), pointed out long ago that the human skin cannot act as a barrier between the mind and the material world: ‘in no system which shows mental characteristics can any part have unilateral control over the whole. In other words, the mental characteristics of the system are immanent, not in some part, but in the system as a whole’ (Bateson, 1971, p. 5, emphasis in original). Minds are not confined within individual brains, bodies or any other isolated locale. Rather, the ‘mental world’ is immanent in the relations and transformations that allow human beings to reach out and to engage (many times consciously and creatively) their surrounding

environments. The anthropologists Edwin Hutchins (2010) and Tim Ingold (2012, 2013), also inspired by Gregory Bateson, use the terms cognitive ecology (the former) and material ecology (the latter) to describe a similar kind of relatedness that characterises the study of the mind in context. The challenge for the cognitive archaeology of stone tools then becomes one of penetrating the ontology of this ‘relational domain’. Cognitive archaeology has an epistemic obligation to try make sense of the evolving human mind (body and brain) from a material culture perspective. To meet this challenge, cognitive archaeology needs to stretch the notion of mind beyond comfortable limits.

2. On the edging of stone

Stones are ever-present in the archaeological record. They come in varying forms and take on various meanings. Stones (found and made) have edges and ridges that, depending on their size and weight, afford particular bodies a variety of ways to be attended and used. ‘Cutting’ is one of those uses that can be argued as a key innovation in the history of our species (Davidson, 2010; Davidson & McGrew, 2005). Cutting is not an affordance for every species. Moreover, although some animals, for instance apes, are capable of learning how to cut a string in the laboratory, they never demonstrate this ability in the wild (Davidson, 2019). To cut you need an edge (teeth and nails are nature’s substitute). The problem is, on one hand, that not every edge is good for cutting, and on the other hand, that not all bodies are good for, or capable of making edges. What does it take to make an edge on a stone?

In a basic sense, lithic artefacts (hand-held cutting edges) are the products of the process of knapping. Percussion-based knapping is using a stone (a hard hammerstone) to strike another (the blank or core) to produce a flake. The significance of this elementary creative gesture in the evolution of our species is well recognised. Not the least because stone tools are the oldest surviving examples of bodily prosthesis, and stone tool making is among the oldest known examples of creative material engagement. However, what is it exactly that gives stoneknapping such a prominent place in the evolution of hominin intelligence? For the contemporary reader who, probably, has never experienced knapping, or even watched a skilled flintknapper at work, it is hard to realise the complexity of actions and skills that this elementary form of material engagement entails.

Perhaps, drawing a simple analogy with a more familiar technique could help: Striking the flint with a hammer is to tool making as striking a key with your finger is to piano playing. I am not comparing the actual practices. Piano playing and stone tool making have very little in common. The comparison is between

striking gestures, enactive intentions and what neuropsychologist Aleksandr Luria called ‘kinetic/kinaesthetic melodies’ (Luria, 1973). Presumably, the striking part is easy, if perceived in isolation. However, the kinetic/kinaesthetic melodies of tool making, not unlike those active in piano playing, place novel biomechanical demands and performance constraints on the hand and the brain (Geribàs et al., 2010; Pargeter et al., 2019; Patten, 2012; Rein et al., 2014; Stout, 2015) that destabilise, potentially, the unidirectional course of Darwinian evolution by natural selection. I say that tool making potentially destabilises directional evolution because I understand the impact of tool making not in a selectionist or computational sense of developing a larger or well-connected brain able to produce and efficiently control complex movement. Rather, I understand it in the enactive sense of learning to *move with* and *think through* the materiality of stone, as this can be experienced through the knapper’s hand and perceived through the knapper’s eye. The stone strikes back through the manipulative complexity (inseparably cognitive, bodily and technical) that it affords.

This article will argue that tool making is not an adaptation in the sense of an evolutionary accomplishment. Adaptationism in the classical sense of the term reiterates an asymmetric approach to evolution based on the split between organism and environment. This view is incompatible with the ecological/enactivist foundation of Material Engagement Theory (MET) where organism and environment form a necessary unity. In this context of transactive distributed intelligence, the conventional meaning of biological adaptation as the fitting of organism to environment mediated by natural selection gives away to a more extensive, enactive and largely semiotic view of adaptability (i.e., as the capacity to become adapted). This is what in the context of MET is referred to as creative *thinging* (Malafouris, 2014, 2019, 2020). The knapping process will be approached as a creative entanglement, a co-constitution of mind and matter. Tool making is not a transposition, externalisation or the imposition of form on raw material but the gathering together of all the different elements—internal or external; neural, bodily or material—needed in order to make an edge of a stone. In this sense, as I explain below, tool making provides a unique case for metaplasticity demonstrating the complex exchange of energies and materials between the human organism and its niche (Malafouris, 2008a, 2008b, 2008c, 2009, 2010b, 2013, 2015; Gosden & Malafouris, 2015). Understanding how stone tools are made opens a window to the process of creative material engagement and the role it has played in human cognitive becoming. Important to clarify here is that the phrase human cognitive becoming is not referring to the evolutionary process by which minds became ‘modern’ in the ‘representational’ sense of the word. The process of human becoming should not be mistaken with the

process of becoming human that is customarily used in discussions of human origins in archaeology. There is no moment, or distinctive stage, in the process of human cognitive evolution where modern thinking emerges as a fixed set of anatomical or genetic features that give rise to the capacity for representation.

In contrast, human intelligence, seen as a mode of becoming, remains actively and creatively incomplete. Cognitive evolution and transformation are ongoing. The dominant understanding of our ‘sapient’ minds, not just as the ‘superior’ intelligence but also as ‘complete’ and ‘fixed’ (adapted to past environments that no longer exist), gives way to a different vision that sees the human mind as an unfinished process, amenable to drastic, deep reorganisation and *prostheses* and thus, potentially, in a permanent state of ongoing creative evolution (Barrett, 2011, 2009, 2010b, 2013; Dupré, 2008; Ingold & Pálsson, 2013; Malafouris, 2015; Malafouris 2016b; Malafouris & Gosden 2020; Gosden & Malafouris 2015). The incompleteness of human becoming argues against the notion of cognitive ‘modernity’. There is a deep contradiction between the notion of a ‘modern mind’ and the notion of metaplasticity (Malafouris, 2008b, 2009, 2010b, 2013, 2015). I do not wish to deny the existence of a distinctive mode of human cognitive becoming. Human becoming is different, in many respects, as it is continuous in others, with the cognitive becoming of other sentient animals. What I object to here is the persistent archaeological habit of viewing the ‘modern’ mind as a set of pre-defined capacities (biological or cultural) whose origins can be explained by appeal to some fortuitous genetic mutation and whose products can be seen reflected in the archaeological record in a series of preconceived fixed behavioural traits. Against that view, MET brings an ecological-enactive perspective that sees the mind as a situated process – that is, an emergent product of complex semiotic ecologies and flexible incorporative forms of material engagement.

3. About making a handaxe

Knapping produces a variety of edges and cutting tools of different shapes and sizes. For my purpose, in this article, I will focus on the example of the first bifacially shaped large cutting tool (also known as the handaxe). Handaxes persist over more than one and a half million years, involving several hominin species and spanning geographically from Africa to Europe to China. Despite the apparent stability of the Acheulean handaxe, there is also variability. A combination of morphometric techniques and metrical analysis has been used to compare the morphology of handaxes of different materials and periods as well as to analyse and better define the different stages of the shaping process from the original blank to the final form. Current research in this context is centring on the functional

and cognitive significance of handaxes for the hominins that made and used them from around 1.7–1.5 Ma.

The debate over the so-called ‘handaxe enigma’ has been focusing especially on whether the symmetry of Acheulean bifaces is intentional (a conscious decision made by the knapper) or a mere consequence of bifacial flaking (e.g. Shipton & Clarkson, 2015a, 2015b; Shipton et al., 2019; Hodgson, 2015; Kohn & Mithen, 1999; McPherron, 2000; Nowell & Lee Chang, 2009). For some researchers, lithic raw material qualities and mechanical constraints were the main determining factors in stone tool morphology. On this construal, perceived morphological differences in handaxes are the by-product of the reduction process (Ashton & White, 2003; White, 1995). Others have argued, on the contrary, that material constraints did not affect the shape and size variability of the handaxes in any significant way (García-Medrano et al., 2019; Sharon, 2008). The characteristic bilateral symmetry and tear-drop shape of this artefact have been interpreted as the product of some form of representation, perhaps a standardised, predetermined ‘mental template’ (García-Medrano et al., 2019; Gowlett, 2006; Roche, 2005; Wynn, 2002). Some would even see in the handaxe the capability for third-order intentionality (Cole, 2016).

In general, we can distinguish two major approaches to the problem of the handaxe. One approach is to look for the cognitive processes involved in the production of the tool, or the cognitive prerequisites for that tool, that is, the cognitive capacities required for an organism to be able to construct and use this kind of tool. The second approach is to focus instead, on the knapping process directly, that is, to focus on the sequence of technical gestures (e.g. the type of percussion support, the position of the blank or the angle of blow) or the ‘design imperatives’ (Wynn & Gowlett, 2018)² that a knapper must learn to handle in order to produce a complex bifacial stone tool like a handaxe (e.g. Geribàs et al., 2010).³ Notice however, that despite their differences, both approaches implicitly agree that mind and tool — or thinking and tool making — are separate. Both approaches look for the mind *behind* the tool. Moreover, in both cases, the link between cognition and tool making is based on the assumption that tools are the products of intentional actions (more correctly a sequence of intentional states, decisions and actions). That is, tools are the products of (a) minds capable of having tool-forming or tool-using intentions and (b) bodies capable of externalising or performing those intentions through a sequence of actions (e.g. a knapping sequence). On this formulation, to understand how stone tools are made, we need to understand, on one hand, the relevant ‘intentional stance’, and on the other hand, the biomechanical actions, bodily skills and gestures that allow the execution or externalisation of that intention on the stone’s surface producing a stone tool (e.g. a flake, a chopper or a handaxe).

Let us focus on what seems to be the major common assumption here, namely, that the knapping process is

intentional or comprised of a series of intentional actions. What is the meaning of the term ‘intentional’ in this context? What exactly do we mean when we say that a handaxe is the product of the knapper’s conscious intention? Are the knapper’s intentional states about flaking or are they about shaping a large bifacially shaped cutting tool? Does the knapper aim to create a tool with bilateral symmetry (Gowlett, 2006; Roche, 2005; Stout, 2011; Wynn, 2002) or just a large cutting tool whose sides converge on a pointed tip? Are the knapper’s intentional states about the different types of technical gestures (e.g. percussion support, the position of the blank or the angle of blow), or the ‘design imperatives’ performed (Wynn & Gowlett, 2018) or the standardised tear-drop residual form that we call a handaxe?

The meaning of the term ‘intentionality’ in archaeology is too vague to have any analytical value. Above all, it remains unclear from where those goals, intentional states and actions come from. The knapper’s intentionality is taken for granted. This forms a major lacuna because technically, in philosophy of mind, ‘intentionality’ refers to the mind’s meaningful directedness at the world, which many philosophers see as the mark of the mental. Intentionality comes from the Latin verb *intendo*, meaning ‘to aim or stretch’, and it has been used in philosophy of mind, particularly in phenomenology, to describe the central feature of human consciousness to be *of* or *about* things (mental or physical), that is, to have direction and content. For instance, according to the classical account of the phenomenologist Franz Brentano (1995), intentionality is the distinctive feature of human mental states: ‘No physical phenomenon exhibits anything like it. We can, therefore, define mental phenomena by saying that they are those phenomena which contain an object intentionally within themselves’ (p. 68).

If it is of the very nature of tool making to be ‘intentional’, then the challenge for cognitive archaeology is to explain what kind of ‘intentional action’ knapping is. The meaning of intentionality in the context of tool making remains open. This applies to percussion as it applies to all the technical gestures that a knapper must learn to control in order to produce a complex bifacial stone tool like, a handaxe. The question is this: When we say that stone tools are made are we to assume that they have derived ‘intentionality’ as the conscious products of a deliberate intentional state, or should we see the tool as an embodiment of intentional action? Put simply, is intentionality the property of the individual, that is, the knapper’s mind or brain? Or is it the property of the knapping process? I will argue for the latter. Specifically, I propose that in the case of knapping, the ‘content’ of the intention (i.e., obtaining sharp edges for cutting, symmetrical or not), is distributed and inseparable from the actual performance of the action plan, and in this sense it can no longer be viewed as ‘content’.

I argue that knapping, like all ‘technical’ actions and prosthetic gestures in human evolution, embodies intentionality in a way that saves the concept from its representational connotation and dualistic assumptions. Intentionality should not be conflated with mental representation. My suggestion is that percussion is not what the knapper’s intentionality is *about*, rather, percussion is the technical action that brings forth the *aboutness* of the knapper.

4. *Thinging stone*

Here is what I see as the main shortcoming in the way the question of the Acheulean biface has traditionally been framed (Malafouris, 2010a, 2013): Despite their differences, all major accounts of the Acheulean handaxe, implicitly identify knapping with some sort of unidirectional causal and intentional process by which the active mind imposes form (intentional states) on the passive stone. In other words, they implicitly assume that the knapper’s intentional states are conscious representational states, or ‘prior intentions’, formed inside the knapper’s head in advance of the action itself. On this view, the knapper’s intention temporally and ontologically precedes and causes the knapper’s hand movement, or sequence of movements, which then, produce the handaxe. By extension, knapping is seen as the intermediate process that translates human ‘intention’ into an ‘artifact’ (the handaxe). This also suggests that the ontology of tools is derivative of human intentionality: Whether we see the content of the knapper’s intentional state in the symmetry of the handaxe (Wynn, 1995), or the production of blades (Noble & Davidson, 1996), it is the knapper who remains the cognitive agent. It is the knapper who possesses the intentional states that are causing all the important decisions about the sequence, the force, the direction and the angle of the blows. In other words, as far as intentionality is concerned, the boundary between the mind and the tool remains intact: Intentional states have a mind-to-world direction of fit, they are *of* or *about* things, whereas things in themselves may not be *of* or *about* anything. It is this strongly internalist commitment to the representational character of these intentional states that I suggest we need to overcome.

I do not mean to deny that the production of a large Acheulean biface (handaxe) involves a series of complex intentions, anticipations and decisions about size, shape, symmetry, thinness and sharpness or that these are different from those involved in Levallois knapping. What I am questioning is the representational logic that implicitly or explicitly situates those cognitive processes inside the head of the knapper and ascribes them causal, temporal and ontological priority over the knapping process. If you start with such a representational presupposition then it necessarily follows that the handaxe can only be the product, or external representation, of

an ‘internal’ pre-formed idea or mental template, which was subsequently realised in the ‘external’ world. Fixing ‘the marks of the cognitive’ in this traditional dualistic sense, the handaxe, like any other tool left in the archaeological record, can only be seen as a kind of ‘external’ trace or residue of cognitive activity proper that has happened elsewhere, that is, in the ‘internal’ cognitive realm proper. But where exactly is this ‘internal’ cognitive realm? Where does the mind stop and the stone tool begin?

As mentioned, the argument I want to put forward from the perspective of MET is that intentions, anticipations and decisions are not of the knapper but of the knapping process. Stone tools are intentional objects, but not because they represent the outcome of a consciously deliberated choice that happened inside the knapper’s head and ahead of the knapping process. Rather stone tools are intentional, because they embody a process of deliberate choice in the enactive-ecological sense. That is, intentional action happens with them, that is, through making and using them. The stone held in the knapper’s hand is more than a passive platform offering the necessary ‘conditions of satisfaction’ for realising the knapper’s intention. The stone projects towards the knapper as much as the knapper projects towards the stone, and together they constitute a *hylonoetic*— from the Greek words *hyle* (matter) and *nous* (mind) — field of intentional, anticipatory and attentive material engagement.

In short, the argument is that the knapping process is not derived or simply the product of the relevant neural activation patterns or intentional capacities of the knapper’s brain, rather it constitutes an active extra-cranial participant of the thinking process. Stone knapping is *thinging stone*, *that is, thinking through, with and about stone*; knapping does not simply execute but rather *brings forth* the knapper’s intentions. No action, or intention, that matters is taken by the knapper in mental isolation from the material. None of the bodily movements or creative gestures can be processed, planned or controlled before the act. Planning, anticipation, intention and imagination all exist but in a situated manner, meaning, they become constituted in action (knapping) that is inseparably neural, bodily and material. As such, the knapping gesture enacts the flaking intention which is constituted, at least partially, by the stone itself. Information about the stone is not internalised and processed by the brain to form the representational content of the knapper’s intentional stance. Both the stone and the knapper’s body are integral and complementary parts of the intention to knap. Every stroke prepares the platform for the next. Every stroke can also reveal something new about the stone’s qualities and affordances. Intention no longer comes before action; mind and action are one. The mental and the physical become one through the process of knapping.

The notion of *skilled intentionality*, defined as ‘the individual’s selective openness and responsiveness to a rich landscape of affordances’, is relevant here (Bruineberg & Rietveld, 2014; Rietveld & Kiverstein, 2014). The notion was developed to provide an account of how there can be intentionality without mental content. The notion of *skilled intentionality* in humans cuts across content-involving forms of intentionality and non-representational forms of intentionality. Instead of the usual distinctions between different forms of intentionality, the key issue becomes one of understanding how skilled intentionality takes different forms in different forms of life. From the perspective of skilled intentionality, the distinction that matters is that between forms of skilled intentionality for which normative standards or questions correctness arise, and varieties of skilled intentionality where all that matters is the individual’s practical grip on the environment. So on this construal, the difference between Oldowan and Acheulean knapping is not one between content-free (non-representational) and content-involving (representational) forms of intentionality – there is no developmental transition involved. Rather, it is a difference between forms of skilled or enactive intentionality. In particular, in the latter case, the handaxe presents a more adequate grip of the relevant material environment and also indicates the emergence of more explicit normative standards concerning aspects of the technical process or the symmetry of the handaxe. However, these normative standards should not be construed in the cognitivist sense of a ‘mental template’. Modes of skilled intentionality and their normative constraints refer to the experience of whole animals situated in particular behavioural settings. Normative standards and constraints are built and maintained as a part of skilled activity rather than as internal representations. Their study demands an ecological approach, which situates skilled practice in the context of material engagement and recognises that it involves both dexterity and multi-modal affective qualities grounded in an attentive, perceptual involvement, or attunement with the tools and materials involved. As Tim Ingold (1997) noted long ago, ‘It is precisely because the practitioner’s engagement with the material is an attentive engagement that skilled activity carries its own intrinsic intentionality, quite apart from any designs or plans that it may be supposed to implement’ (p. 111).

This by no means denies that the knapping process is intrinsically associated with, follows from and leads to specific patterns of neural activation (See Bruner & Gleeson, 2019; Bruner & Iriki, 2016; Malafouris, 2008b, 2008c, 2009; Stout, 2011, 2015; Stout et al., 2008). We can rightly assume there are brains attuned with bodies as there are hands attuned with tools, but there is no indication that the former merits more attention than the later when it comes to studying human cognitive becoming. The argument is not that the brain

is not important. The argument is that recognising the importance of the brain by no means implies that the cognitive dimensions of the knapping process should be reduced to neural processes. There is no empirical reason why neural processes should be given causal or explanatory primacy over actions and materials. Although one may well read a correlation between the performance of a certain task, for example, knapping, and the observed patterns of increase or decrease in regional brain activity, this correlation should not be confused with identity (Malafouris, 2008b, 2008c; Malafouris & Renfrew, 2008). No measure or measurement of what is going on *within* the brain during performance of a task can, in itself, explain or substitute for the cognitive life of that task. This is also how new neuroimaging studies should be interpreted (Stout & Chaminade, 2007; Stout et al., 2008). Seeing knapping in that way avoids the usual neurocentric fallacies that take the brain as the executive controller for activity; rather, it is the other way around: Now it is activity that controls the brain. Human thought ‘stays *with* the body rather than *within* the body’ (Malafouris, 2013, p. 174). In fact, the majority of available neuroarchaeological evidence shows that stone tool making can elicit plastic structural responses in evolutionarily relevant brain structures (lateral frontal, parietal and temporal association cortices are among the most volumetrically expanded portions of the human brain). Although the exact nature of the interaction between Palaeolithic tool making and human brain evolution is unclear, what is becoming increasingly recognised is that changes in the human brain are responsive to systemic dynamics and should not be seen as causing the relevant behaviours of interest (Bruner & Gleeson, 2019; Bruner & Iriki, 2016; Malafouris, 2008b, 2009; Stout, 2011, 2015; Stout et al., 2008).

Knowing what the brain is doing when a knapper produces an edge is useful and important as is to know how the rest of the knapper’s body is engaging the stone. No isolated dimension (bodily or neural) of the knapping process suffices, in and of itself, to account for the phenomenon as a whole. In fact, one could argue that if there is a central executive area guiding and controlling the knapping sequence, it is not to be found at prefrontal areas of the hominin brain, but at the power grip and morphology of the hominin hand. Knapping is causing the hand to move, drawing the attention of the brain to the changing state of the stone and recruiting the relevant neural activation patterns in the cortex of the knapper. Knapping binds time as it binds intention. Causality and human agency are simply the products – very often illusory – of such an experience.

Moreover, although from the perspective of a present day knapper the intention to flake stone, in one way or another, may seem well defined and fully formed in advance of the knapping process, from a cognitive archaeology perspective, this is not an

experience that we can take for granted in the case of the hominin knapper. In the latter case, the very presence and nature of intentionality is precisely what needs to be established. I suggest that if there was a concept or intention about cutting something in the head of the knapper, then it makes better sense to assume that this was initially formed through the knapper's exploratory or accidental engagement with edges or the edge-like properties of stone, than assume the intention was fully formed in advance of experience. You can never form an intention to open a door without knowing what doors do, and this something you learn from experience. As we discussed relevant to notions of affordance and skilled intentionality, the possibilities for action the environment offers are not objective but relational. They depend on the skills, abilities and biological constraints of a given life form, in a specific time, and in relation to specific actions in specific sociomaterial environment. With learning and the development of new skills, the affordances may well change. Affordances are not static; 'affordances are relations between aspects of a material environment and abilities available in a form of life' (Rietveld & Kiverstein, 2014, p. 335).

That is why I suggest that, from the perspective of cognitive archaeology, we should not be asking 'what is the exact intention behind the handaxe?' or about the precise content of the knapper's 'intentional states' (e.g. a cutting instrument rather than a symmetric cutting instrument). The main issue underlying the handaxe enigma is not whether hominins were producing intentional states of one sort rather than another. The issue does not lie in deciding between a core and a blade. Rather, the question we should ask concerns the role that the handaxe, or for that matter of any other tool, may have played in the constitution of human deliberation based on enactive intentional skills. In particular, the question of special interest for cognitive archaeology is how did humans, contrary to other tool using animals, come to possess reflective awareness of their enactive or skilful intentionality? Or else, how did humans become aware of the intentional and anticipatory character of their actions and of the actions of others?

Answering those questions means that we must try to disentangle two central aspects of the problem. One aspect relates to the intentional character of the handaxe. The other concerns the actual constitution and implementation of the intention that brings forth the handaxe. That is, it pertains to the way the knapper relates as a cognitive agent to its surrounding environment and the role the handaxe itself might have played in the constitution of human intentionality and sense of agency. We should not think of this process of making as one where a pre-formed subjectivity projects and imposes form and meaning on matter. Rather, stone tool making is better described as the relational and

sensuous prosthetic becoming by which humans learned to attend to and transform their world. Similarly, there are no fixed agential roles in this process. The knapper first thinks *through* and *with* the stone before being able to think *about* the stone as a conscious and reflectively aware agent.

5. Prosthetic gestures

To help us re-conceptualise the ecology and plasticity of the human mind, the famous phenomenological example of the blind man with a stick has been employed as a working hypothesis in the context of MET (Malafouris, 2008b, 2013, 2020). The transactional character of the relation between the blind person and the stick provides a diachronic point of reference for conceptualising the role of prosthesis in human evolution. Especially in the case of tool making and tool using, the blind man's stick (BMS) hypothesis raises a simple but powerful challenge against the legitimacy of the traditional boundaries of skin and skull and help us to redraw the line that separates brains, bodies and things. The objective of this challenge is not to abolish boundaries altogether; rather, the objective is to question the authority of fixed boundaries and assist us in rediscovering their border-like ontology. Boundaries, as Richard Sennett (2008, p. 227) proposes using an example from natural ecology, are like cell walls. Borders, in contrast, resemble the cell membrane. A boundary is 'simply an edge where things end'; a border, by contrast, is a site of exchange and interaction. I suggest that the sharp edge of a cutting tool has border-like qualities: It is not a boundary in the sense of an end but a point of interaction and perturbatory mediation. A flaked stone used for cutting has the potential to alter relationships between humans, and between humans and their environments. In fact, even the debris of stone flaking left in the environment can be seen as a recourse for niche construction (Davidson, 2019; Davidson & McGrew, 2005). The analogy I am making here with the BMS can be understood in a double sense: first, in terms of the shifting boundaries and prosthetic osmosis between the hand and the tool; second, and more specifically related to tool making, in terms of the exploratory imagination enacted during knapping. In particular, each flaking act (striking the core), like the tapping with the stick, enacts the way forward. Flaking stone brings forth the exploratory movement that will produce the edge of the tool; tapping with the stick brings forth the exploratory movement that will allow the blind to travel from point 'A' to point 'B'.

Through making and using tools, the human species – much like the blind person in our example – discovered the agencies of matter and enacted new pathways of movement. Intelligence begins with intentional

movement (see Sheets-Johnstone, 1998). Evolutionarily speaking, the main reason we have a brain is to *move* from point 'A' to point 'B'. To begin with, moving was thinking. All bodily movement is not fully controlled or intentional, yet it always embodies elements or traces of enactive intentionality (in the sense of intention-in-action). This is especially true in tool making, in which the enactive intention is cutting. Movements also have energetic costs, and from an evolutionary perspective, it makes sense to assume that skilled movement must be efficient and optimal in terms of accomplishing the task at the lowest cost. Adopting the computational stance, one could probably describe that process using some optimal feedback motor control system housed inside the brain with the abilities to (a) accurately predict the sensory consequence of our motor commands (forward model), (b) combine these predictions with actual sensory feedback to form a judgement about the state of our body and the world, and (c) use those estimations for adjusting our sensorimotor feedback loops so that our movements can maximise performance balancing the costs and rewards of our movement (Yarrow et al., 2009). That's all fine if you assume that the brain has the role of an executive controller over the body and that the human mind is nothing but a neurally implemented computational system. But for cognitive archaeology, such a restrictive view of the mind is inadequate to explain how such a computational system emerges out of an acting and moving body as well as the observed variety and flexibility in the way hominins realise and specify their precise movement paths and patterns of situated activity. This is especially true in the case of tool making where this elementary ability for movement acquired conscious purpose, direction, and collective meaning. This transformation was possible through diverse reduction sequences comprising a series of technical gestures (e.g., Roux et al., 1995). The human sense of agency and *tectonoetic* consciousness (Malafouris, 2008b) also emerged out of this process. Those technical gestures comprise the basic units in the choreography of the knapping movement. It is the cognitive life of that movement and its component gestures that we need to understand. However, we should not be thinking of tool making as a pre-ordered gathering of movements and skills that are joined together in a sequence of attentive postures, creative gestures and intentional actions to produce a new object. What matters is not just the outcome of the movement, but the movement itself. Knapping movements always happen in context. They are movements that remember their past (leaving their traces on the rock's surface) and imagine a future (anticipating and predicting the position of the next strike). Within such multimodal processes of creative material engagement, it is especially hard to maintain the old distinctions between the domains of perception, cognition and action.

6. Conclusion

What does all this tell us about mind, stone tools and the relationship between them? In the final section of the article, I offer a summary of the key insights about thinking and tool making that follow from our discussion. As we saw, at present, there is lack of critical discussion over the meaning of cognition in the context of archaeological discourse (i.e. in the context of problems and research questions related to embodied material practices and their transformation over longer timescales). This is a major problem for the archaeology of mind. Not least because archaeologists end up adopting uses and borrowing meanings of those concepts from other disciplines that operate on different timescales and have different problems to solve and questions to answer. This attitude explains how cognitivism came to dominate the way most archaeologists think about the process of thinking and the process of creativity in particular. It is also responsible for another common assumption: that archaeologists cannot dig up minds. This is an assumption that clearly implies that minds are well-defined entities of which we know, with a great deal of certainty, that they do not survive in the archaeological record. This can only be true if you equate mind with the brain. But this implicit equation of the mind with the brain or some other 'internal' substance, far from natural, is only one among many ways to look at the issue of cognitive boundaries. As I have said many times, understanding the neural dimension of human cognitive becoming is crucial. However, neurocentrism has been the source of continuous problems and confusion in cognitive archaeology. Those problems are especially prominent in the field of lithic studies, where there has been considerable discussion and debate over the cognitive demands, or dimensions of stone-tool making. A closer look in the relevant literature reveals a number of, in my view, unhelpful conjectures about the nature of creativity and the meaning of intentional action, as well as about the actual links between cognition, materials and techniques. These problems have to do with the conceptualisation of the lithic objects as artefacts, that is, the intentional products of the knapping process, as well as with the way we draw the boundary between thought, material and action (see Dibble et al., 2017; Gibson & Ingold, 1993; Holdaway & Douglass, 2012; Overmann & Coolidge, 2019; Pargeter et al., 2019).

I have argued in this article that attaining some clarity on the question of cognitive boundaries is a precondition for making progress and integrating research around those key issues in human evolution and the archaeology of mind. My aim in making our conception of those boundaries more explicit is not to bring agreement among scholars on the hard question of

what makes something a cognitive process. My ambition is simply to highlight the importance of cognitive archaeology and of lithic studies in particular, as a space for meaningful critical dialogue, or productive disagreement, on basic questions about what mind is and does: What is human cognition? What counts as cognitive? What is that we call 'mind' in the archaeology of mind?

As we saw, the traditional understanding of what it means to provide a cognitive explanation or account of tool making and tool using has been to provide a mental substitute or cause that can explain the forming, use and otherwise coming to be of a tool. The inherited ontological split between cognition and material culture forced cognitive archaeology to define its major epistemological objectives as an attempt to infer, in the first instance, behaviour (e.g., stone knapping, subsistence activities or raw material procurement), and, in the second instance, the cognitive prerequisites for that behaviour from the material remains of the lithic record (e.g., measured in terms of hierarchical complexity, attention spans or neurophysiological demands). Most researchers would agree that the main question that cognitive archaeology should be answering is one about the kind of cognitive capacities required for an organism to be able to construct and use a specific kind of tool. This applies both to Oldowan flake and core technologies (~2.6–1.7 Mya) and to Acheulean large cutting tools like, handaxes and cleavers (~1.75–0.3 Mya).

By adopting an ecological-enactive outlook, this article has suggested that we get rid of our engrained modernist convictions about where the mind is, and about how it relates to the rest of the body and the world. MET provides the basis for a very different conceptualisation according to which (a) what is considered to be 'inside' and what is considered to be 'outside' the mind cannot be defined a priori, but only in relation to specific bodies (human or nonhuman) that are engaged in a specific task (e.g., knapping stone), and (b) the relation between thinking and making can no longer be described as a unidirectional causal sequence of 'mental' states leading to 'physical' actions; it can only be described as an ontological entanglement of the mental with the physical. This theoretical foundation allows us to capture intelligent action and defines intelligence based on what is found in the lithic record and on what can be observed through comparative and actualistic/experimental studies of tool making. A number of studies already exist that blend such ergonomic and enactive conceptualisations of material thinking, seeking to re-describe the process of tool making (Overmann & Wynn, 2019a, 2019b; Wynn & Gowlett, 2018). Moreover, comparative studies focusing on modern-day knappers, either in experimental settings (Bril et al., 2010) or in ethnographic contexts (Stout, 2002), have been exploring in detail the different stages of the knapping process as well as the basic technical

gestures that comprise this elementary form of human becoming (Bril et al., 2015, 2010; Geribàs et al., 2010; Nonaka et al., 2010; Roux & David, 2005; Roux et al., 1995; Stout, 2002; Stout & Chaminade, 2007).

MET builds on that background of empirical and experimental work by proposing a radical re-description of the cognitive geography of action and the distribution of cognitive labour. This ecological-enactive theoretical foundation could be used to integrate new research on the cognitive, motor and kinaesthetic dimensions of the knapping process and the skills of the hand. Once the meaning of 'cognitive' is reconfigured, the classical definition and scope of cognitive archaeology can be seen in a new light. The kind of reductive explanation or ultimate cause that traditional ways of practicing cognitive archaeology seek inside the head of the prehistoric individual now give way to a relational account that focuses equally on the skills of the hand and the affordances of the material. Thus, what we see in the archaeological record is not the secondary product of a thinking process that happened in a different domain; rather, we see a part of that cognitive process situated in a 'rich landscape of affordances' (Rietveld & Kiverstein, 2014) presented to us through the material remains of the past. Not just the changing forms of tools but minor features, like the number of scars or the size and shape of impact points left on the surface of a core recovered from an archaeological site, provide enactive material signs that help us reconstruct this landscape of semiotic and kinaesthetic affordances.

Traditional behaviourist and functional approaches to the study of tool making and tool using have been relying primarily on external inputs as the precursors of action. Cognitive approaches had changed that by acknowledging the importance of internal mental operations as preceding action and thus mediating specific behavioural responses to external stimuli. A simple way to understand MET is to see it as an attempt to unify and integrate behavioural/material and cognitive ecologies/approaches through a radical reconceptualisation of the relationship between cognition and material culture. Tool making can help us to visualise this ontological mixture of material and cognitive ecologies. In particular, mindless behaviourism and cognitivism give way to a cognitive ecology of action.

This shift in the unit of analysis has some important implications on how we define the cognitive and we draw the boundaries of the cognitive system. Mind is not limited by the skin (Bateson, 1972). Thinking is an *active process* that takes place inside the world; rather than inside our heads. Such a view obviously demands that we rethink what counts as a cognitive explanation and what we mean when we talk about the cognitive bases or demands of tool making and tool using (Vaesen, 2012; Malafouris, 2012). What do we mean, for instance, when we speak of cognitive equivalence or

variation between chimpanzee nut cracking and early stone-tool knapping? (e.g. Bril et al., 2015; Lombard et al., 2019; Godfrey-Smith, 2016). What exactly are we comparing when we talk about cognitive continuity or discontinuity between us and our closest relatives, or in general between humans and nonhuman animals?

Elsewhere revisiting the notion of *Homo faber* in archaeology (Ihde & Malafouris, 2019), I suggested that questions of continuity or discontinuity are inherently imprecise because they presuppose that we can readily determine that there is a some general fundamental difference or similarity between humans and other entities (human or non-human). This is not the place we can give this topic the attention it deserves. It will suffice to point out, relevant to our discussion, the following: If I see continuities along the hominin line so far as the making and using of cutting tools are concerned, is not because of the percentage of DNA that we share. Rather, it is because no less than 99.8% of the known 2.6 Ma (or perhaps now 3.3 Ma) history of hominin engagement with cutting tools was spent in percussive stone tool making (Whiten, 2015, p. 1). It is the persistent practice of percussive stone tool making that generates continuity by bringing forth a network of constituent processes with sufficient unity, not the way genes code for traits. There is only one uniformitarian assumption to which cognitive archaeology can safely adhere, so far as the making of tools is concerned, and that is that stones flake in the present just like they flaked in the past. As long as our analyses remain grounded to the materiality of stone and the ecology of knapping comparing lithic manufacture in the past and present, as well as among different animals, remains a legitimate epistemic enterprise. This is also why, from the perspective of MET, replicative lithic experiments constitute one of the most valuable forms of practicing cognitive archaeology. As mentioned earlier, bifacial flaking requires fine-tuning between the perceived possibilities for action and the knapper's prereflective capacities for action. In that sense, the study of stone knapping provides a natural experimental setting where the relational ecology of Gibsonian affordances (Gibson, 1979) meet the immersive embodied experience of Merleau-Ponty's (1945/1962; Dreyfus, 2014) 'skilful coping' as well as recent enactive frameworks of 'skilled intentionality' (Bruineberg & Rietveld, 2014; Rietveld & Kiverstein, 2014) and 'predictive engagement' (Gallagher & Allen, 2018).

No doubt the brains, the bodies, the hands and the skills of different individuals are both similar and different. The degree of their similarity or difference depends on the specifics of investigation and the scale of analysis. In some contexts and for some questions, similarities will be more important than the differences. For other contexts and questions, the opposite can be true: it will be the differences that matter. How similar or different minds and tools are depends on what questions

we ask of them and on the basis of what assumptions. In other words, what matters is how we set the conditions of comparability that make our comparative studies valid within a specific epistemological context. As a simple rule of thumb, I suggest we focus on the cognitive ecology of tool making and using following the entanglement of the hand and the material.

All thinking happens where the hand meets the stone. Perception, memory, attention, intention, estimation, expectation, prediction and anticipation take the form of a dialogue between the maker and the material that sometimes agrees and sometime resists. Every act of making (not just the making of a stone tool) is an act of collaboration between the agency of human bodies and the agency of materials, reflecting a world where the neural side of the mental domain is constantly shaped and negotiated by the force of the hand and the affordances of the stone. I have been talking about tool making and tool using in a way that implies not just the use of a tool by an animal or human body but also the use of the human or animal body by the tool. Making is no longer the sequential unfolding of mind into matter via the medium of bodily action (Malafouris, 2020; Gosden & Malafouris, 2015; Koukouti & Malafouris, 2020). Making is thinking in action. I do not mean that thoughts are expressed in material form. I mean that the actual *material expression is the thinking*—at least the thinking that matters to the scales of archaeological time. My aim is not to reverse the direction of causality between internal and external forces, but rather, to problematise our understanding of both direction and causality, as well as critique the internal/external divide. Contrary to the view in which tools are thought of as arbitrary preconceived designs imposed on materials, I suggested that the knapping act should be considered as a process of creative *thinging* where the imaginary (mental aspect of design) and the materiality of stone merge in what we often describe as reduction sequences. There is no mind behind the tool. What we see as an externalisation or imposition of mind *over* matter can be better described as a transaction of mind *with* matter. Intentions, predictions and imaginations are constituted through the act of stone making. Mind exists through the material expressions that are said to be its products. Tool making and using are ways of thinking, not the results of thinking.

Declaration of conflicting interest


The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship and/or publication of this article: The research and writing of this article was supported by the European Research Council Consolidator Grant

HANDMADE (No. 771997; European Union Horizon 2020 programme) awarded to L. Malafouris.

ORCID iD

Lambros Malafouris  <https://orcid.org/0000-0003-2140-4998>

Notes

1. For some recent discussion in philosophy about the nature of those ‘minimal-capacity inferences’ and ‘cognitive-transition inferences’ (see Currie, 2018; Currie & Killin, 2019; Pain, 2019).
2. John Gowlett and Tom Wynn use the acronym GLOBFELTS referring to the six basic ergonomic elements that all handaxes share: glob-butt, forward extension, support for the working edge, lateral extension, thickness adjustment and skewness. As the characteristically observe, ‘this neologism is awkward and even phonetically silly, but therein lies its usefulness; it has no intellectual, definitional, or functional baggage. There is also something tactile about it, thereby emphasizing its ergonomic origin’ (Wynn & Gowlett, 2018).
3. Within this broad gesture-oriented experimental of special interest are recent attempts to identify, characterise and quantify the smallest unit of any knapping action, that is, the manual gesture, and use this elementary unit as a measure of technical complexity during different lithic knapping sequences. This ‘primordial gestural core’ is composed of five gestural variables and has been present/identified in the knapping sequences of three tools: choppers, chopping tools and handaxes. Adopting such a smallest unit of knapping approach focusing on manual gesture can provide a productive basis for comparing different techniques performed throughout the Pleistocene (Cueva-Temprana et al., 2019).

References

- Adams, F. (2010). Why we still need a mark of the cognitive. *Cognitive Systems Research*, 11(4), 324–331.
- Ashton, N., & White, M. J. (2003). Bifaces and raw materials: Flexible flaking in the British early Paleolithic. In M. Soressi, & H. L. Dibble (Eds.), *Multiple approaches to the study of bifacial technologies* (pp. 109–123). Museum of Archaeology and Anthropology.
- Barrett, J. C. (2013). The archaeology of mind: It’s not what you think. *Cambridge Archaeological Journal*, 23(1), 1–17.
- Bateson, G. (1971). The cybernetics of ‘self’: A theory of alcoholism. *Psychiatry*, 34(1), 1–18. <https://doi.org/10.1080/00332747.1971.11023653>
- Bateson, G. (1972). *Steps to an ecology of mind: Collected essays in anthropology, psychiatry, evolution, and epistemology*. University of Chicago Press.
- Brentano, F. (1995). *Psychology from an empirical standpoint* (A. C. Rancurello, D. B. Terrell, & L. L. McAlister, Trans.). Routledge.
- Bril, B., Parry, R., & Dietrich, G. (2015). How similar are nut-cracking and stone-flaking? A functional approach to percussive technology. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1682), 20140355.
- Bril, B., Rein, R., Nonaka, T., Wenban-Smith, F., & Dietrich, G. (2010). The role of expertise in tool use: Skill differences in functional action adaptations to task constraints. *Journal of Experimental Psychology: Human Perception and Performance*, 36(4), 825–839. <https://doi.org/10.1037/a0018171>
- Bruineberg, J., & Rietveld, E. (2014). Self-organization, free energy minimization, and optimal grip on a field of affordances. *Frontiers in Human Neuroscience*, 8, Article 599. <https://doi.org/10.3389/fnhum.2014.00599>
- Bruner, E., Fedato, A., Silva-Gago, M., Alonso-Alcalde, R., Terradillos-Bernal, M., Fernández-Durantes, M. A., & Martín-Guerra, E. (2018). Cognitive archeology, body cognition, and hand-tool interaction. *Progress in Brain Research*, 238, 325–345.
- Bruner, E., & Gleeson, B. T. (2019). Body cognition and self-domestication in human evolution. *Frontiers in Psychology*, 10, Article 1111.
- Bruner, E., & Iriki, A. (2016). Extending mind, visuospatial integration, and the evolution of the parietal lobes in the human genus. *Quaternary International*, 405, 98–110.
- Chazan, M. (2015). Technological trends in the Acheulean of Wonderwerk Cave, South Africa. *African Archaeological Review*, 32, 701–728.
- Chemero, A. (2009). *Radical embodied cognitive science*. MIT Press.
- Clark, A. (2008). *Supersizing the mind: Embodiment, action, and cognitive extension*. Oxford University Press.
- Cole, J. (2016). Accessing hominin cognition: Language and social signaling in the lower to middle Palaeolithic. In T. Wynn, & F. L. Coolidge (Eds.), *Cognitive models in Palaeolithic archaeology* (pp. 157–195). Oxford University Press.
- Crane, T. (1998). Intentionality as the mark of the mental. *Royal Institute of Philosophy Supplements*, 43, 229–251.
- Cueva-Temprana, A., Lombao, D., Morales, J. I., Geribàs, N., & Mosquera, M. (2019). Gestures during knapping: A two-perspective approach to Pleistocene Technologies. *Lithic Technology*, 44(2), 74–89.
- Currie, A. (2018). *Rock, bone, and ruin: An optimist’s guide to the historical sciences*. MIT Press.
- Currie, A., & Killin, A. (2019). From things to thinking: Cognitive archaeology. *Mind Lang*, 34(2), 263–279.
- Davidson, I. (2010). Stone tools and the evolution of hominin and human cognition. In A. Nowell & I. Davidson (Eds.), *Stone tools and the evolution of human cognition* (pp. 185–205). University Press of Colorado.
- Davidson, I. (2019). Evolution of cognitive archaeology through evolving cognitive systems: A chapter for Tom Wynn. In K. A. Overmann, & F. L. Coolidge (Eds.), *Squeezing minds from stones: Cognitive archaeology and the evolution of the human mind* (pp. 79–101). Oxford University Press.
- Davidson, I., & McGrew, W. C. (2005). Stone tools and the uniqueness of human culture. *Journal of the Royal Anthropological Institute*, 11, 793–817.
- Dibble, H. L., Holdaway, S. J., Lin, S. C., Braun, D. R., Douglass, M. J., Iovita, R., McPherron, S. P., Olszewski, D. I., & Sandgathe, D. (2017). Major fallacies surrounding stone artifacts and assemblages. *Journal of Archaeological Method and Theory*, 24(3), 813–851.

- Dreyfus, H. L. (2002). Intelligence without representation: Merleau-Ponty's critique of mental representation. *Phenomenology and the Cognitive Sciences*, 1, 367–383.
- Dreyfus, H. L. (2014). *Skillful coping: Essays on the phenomenology of everyday perception and action*. Oxford University Press.
- Dupré, J. (2008). Against maladaptationism: Or what's wrong with evolutionary psychology? In M. Mazzotti (Ed.), *Knowledge as social order: Rethinking the sociology of Barry Barnes* (pp. 165–180). Ashgate.
- Fedato, A., Silva-Gago, M., Terradillos-Bernal, M., Alonso-Alcalde, R., Martín-Guerra, E., & Bruner, E. (2019). Electrodermal activity during Lower Paleolithic stone tool handling. *American Journal of Human Biology*, 31(5), Article e23279.
- Gallagher, S. (2017). *Enactivist interventions: Rethinking the mind*. Oxford University Press.
- Gallagher, S., & Allen, M. (2018). Active inference, enactivism and the hermeneutics of social cognition. *Synthese*, 195(6), 2627–2648.
- García-Medrano, P., Ollé, A., Ashton, N., & Roberts, M. B. (2019). The mental template in handaxe manufacture: New insights into Acheulean lithic technological behavior at Boxgrove, Sussex, UK. *Journal of Archaeological Method and Theory*, 26(1), 396–422.
- Geribás, N., Mosquera, M., & Vergès, J. M. (2010). What novice knappers have to learn to become expert stone toolmakers. *Journal of Archaeological Science*, 37(11), 2857–2870.
- Gibson, J. J. (1979). *The ecological approach to visual perception*. Houghton Mifflin.
- Gibson, K. R., & Ingold, T. (Eds.). (1993). *Tools, language and cognition in human evolution*. Cambridge University Press.
- Godfrey-Smith, P. (2016). *Other minds: The octopus, the sea, and the deep origins of consciousness*. Macmillan.
- Gosden, C., & Malafouris, L. (2015). Process archaeology (P-Arch). *World Archaeology*, 47, 701–717.
- Gowlett, J. (2006). The elements of design form in Acheulian bifaces: Modes, modalities, rules and language. In N. Goren-Inbar, & G. Sharon (Eds.), *Axe age: Acheulian tool-making from quarry to discard* (pp. 203–222). Equinox.
- Hodgson, D. (2015). The symmetry of Acheulean handaxes and cognitive evolution. *Journal of Archaeological Science: Reports*, 2, 204–208.
- Holdaway, S., & Douglass, M. (2012). A twenty-first century archaeology of stone artifacts. *Journal of Archaeological Method and Theory*, 19(1), 101–131.
- Hutchence, L., & Debackere, S. (2018). An evaluation of behaviours considered indicative of skill in handaxe manufacture. *Lithics*, 39, 36–51.
- Hutchins, E. (2010). Cognitive ecology. *Topics in Cognitive Science*, 2, 705–715.
- Hutto, D., & Myin, E. (2017). *Evolving enactivism: Basic minds meet content*. MIT Press.
- Ihde, D. (1990). *Technology and the lifeworld: From garden to earth*. Indiana University Press.
- Ihde, D., & Malafouris, L. (2019). Homo faber revisited: Post-phenomenology and material engagement theory. *Philosophy & Technology*, 32(2), 195–214.
- Ingold, T. (1997). Eight themes in the anthropology of technology. *Social Analysis: The International Journal of Social and Cultural Practice*, 41(1), 106–138.
- Ingold, T. (2012). Toward an ecology of materials. *Annual Review of Anthropology*, 41, 427–442.
- Ingold, T. (2013). *Making: Anthropology, archaeology, art and architecture*. Routledge.
- Ingold, T., & Pálsson, G. (Eds.). (2013). *Biosocial Becomings: Integrating Social and Biological Anthropology*. Cambridge: Cambridge University Press.
- Key, A., Merritt, S. R., & Kivell, T. L. (2018). Hand grip diversity and frequency during the use of Lower Palaeolithic stone cutting-tools. *Journal of Human Evolution*, 125, 137–158.
- Kirchhoff, M. D., & Kiverstein, J. (2019). How to determine the boundaries of the mind: A Markov blanket proposal. *Synthese*. Advance online publication. <http://dx.doi.org/10.1007/s11229-019-02370-y>
- Kivell, T. L. (2015). Evidence in hand: Recent discoveries and the early evolution of human manual manipulation. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1682), 20150105.
- Kohn, M., & Mithen, S. (1999). Handaxes: Products of sexual selection? *Antiquity*, 73(281), 518–526.
- Koukouti, M. D., & Malafouris, L. (2020). Material imagination: An anthropological perspective. In A. Abraham (Ed.), *The Cambridge handbook of the imagination* (pp. 30–46). Cambridge University Press.
- Leroi-Gourhan, A. (1993). *Gesture and speech* (A. B. Berger, Trans.). MIT Press.
- Lombard, M., Högberg, A., & Haidle, M. N. (2019). Cognition: From capuchin rock pounding to Lomekwian flake production. *Cambridge Archaeological Journal*, 29(2), 201–231.
- Luria, A. R. (1973). *The working brain* (B. Haigh, Trans.). Penguin Books.
- Lycett, S. J., & Eren, M. I. (2019). Built-in misdirection: On the difficulties of learning to knap. *Lithic Technology*, 44(1), 8–21.
- Malafouris, L. (2008a). At the potter's wheel: An argument for material agency. In C. Knappett, & L. Malafouris (Eds.), *Material agency: Towards a non-anthropocentric perspective* (pp. 19–36). Springer.
- Malafouris, L. (2008b). Beads for a plastic mind: The 'blind man's stick' (BMS) hypothesis and the active nature of material culture. *Cambridge Archaeological Journal*, 18(3), 401–414.
- Malafouris, L. (2008c). Between brains, bodies and things: Tectonoetic awareness and the extended self. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363, 1993–2002.
- Malafouris, L. (2009). 'Neuroarchaeology': Exploring the links between neural and cultural plasticity. *Progress in Brain Research*, 178, 251–259.
- Malafouris, L. (2010a). Knapping intentions and the marks of the mental. In L. Malafouris & C. Renfrew (Eds.), *The cognitive life of things: Recasting the boundaries of the mind* (pp. 13–27). McDonald Institute for Archaeological Research.
- Malafouris, L. (2010b). Metaplasticity and the human becoming: Principles of neuroarchaeology. *Journal of Anthropological Sciences*, 88, 49–72.

- Malafouris, L. (2012). Prosthetic gestures: How the tool shapes the mind. *Behavioral and Brain Sciences*, 35(4), 28–29.
- Malafouris, L. (2013). *How things shape the mind: A theory of material engagement*. MIT Press.
- Malafouris, L. (2014). Creative thinging: The feeling of and for clay. *Pragmatics and Cognition*, 22, 140–158.
- Malafouris, L. (2015). Metaplasticity and the primacy of material engagement. *Time and Mind*, 8, 351–371.
- Malafouris, L. (2016a). Material engagement and the embodied mind. In T. Wynn & F. L. Coolidge (Eds.), *Cognitive models in Palaeolithic archaeology* (pp. 69–82). Oxford University Press.
- Malafouris, L. (2016b). On human becoming and incompleteness: A material engagement approach to the study of embodiment in evolution and culture. In G. Etzelmüller, & C. Tewes (Eds.), *Embodiment in evolution and culture* (pp. 289–305). Mohr Siebeck.
- Malafouris, L. (2018). Bringing things to mind: 4Es and material engagement. In A. Newen, L. De Bruin, & S. Gallagher (Eds.), *The Oxford handbook of 4E cognition* (pp. 755–771). Oxford University Press.
- Malafouris, L. (2019). Mind and material engagement. *Phenomenology and the Cognitive Sciences*, 18, 1–17.
- Malafouris, L. (2020). Thinking as ‘thinging’: Psychology with things. *Current Directions in Psychological Science*, 29(1), 3–8.
- Malafouris, L., & Renfrew, C. (2008). Steps to a ‘neuroarchaeology’ of mind: Introduction. *Cambridge Archaeological Journal*, 18, 381–385.
- Malafouris, L., & Gosden, C. (2020). Material engagement, plasticity, and the developmental challenge. In I. Gaskell, & S. A. Carter (Eds.), *The Oxford handbook of history and material culture* (pp. 105–120). Oxford University Press.
- Mateos, A., Terradillos-Bernal, M., & Rodríguez, J. (2019). Energy cost of stone knapping. *Journal of Archaeological Method and Theory*, 26(2), 561–580.
- McPherron, S. P. (2000). Handaxes as a measure of the mental capabilities of early hominids. *Journal of Archaeological Science*, 27(8), 655–663.
- Merleau-Ponty, M. (1962). *Phenomenology of perception* (C. Smith, Trans.). Routledge. (Original work published 1945)
- Moore, M. W., & Perston, Y. (2016). Experimental insights into the cognitive significance of early stone tools. *PLOS ONE*, 11(7), Article e0158803.
- Newen, A., De Bruin, L., & Gallagher, S. (Eds.). (2018). *The Oxford handbook of 4E cognition*. Oxford University Press.
- Noble, W., & Davidson, I. (1996). *Human evolution, language and mind: A psychological and archaeological inquiry*. Cambridge University Press.
- Nonaka, T., Bril, B., & Rein, R. (2010). How do stone knappers predict and control the outcome of flaking? Implications for understanding early stone tool technology. *Journal of Human Evolution*, 59, 155–167.
- Nowell, A., & Lee Chang, M. (2009). The case against sexual selection as an explanation of handaxe morphology. *Paleoanthropology*, 2009, 77–88.
- Overmann, K. A., & Coolidge, F. L. (Eds.). (2019). *Squeezing minds from stones: Cognitive archaeology and the evolution of the human mind*. Oxford University Press.
- Overmann, K. A., & Wynn, T. (2019a). Materiality and human cognition. *Journal of Archaeological Method and Theory*, 26(2), 457–478.
- Overmann, K. A., & Wynn, T. (2019b). On tools making minds: An archaeological perspective on human cognitive evolution. *Journal of Cognition and Culture*, 19(1–2), 39–58.
- Pain, R. (2019). What can the lithic record tell us about the evolution of hominin cognition? *Topoi*. Advance online publication. <https://doi.org/10.1007/s11245-019-09683-0>
- Pargeter, J., Khreisheh, N., & Stout, D. (2019). Understanding stone tool-making skill acquisition: Experimental methods and evolutionary implications. *Journal of Human Evolution*, 133, 146–166.
- Patten, B. (2012). Explaining temporal change in artifacts by the use of process controls. *Lithic Technology*, 37, 25–34.
- Rein, R., Nonaka, T., & Bril, B. (2014). Movement pattern variability in stone knapping: Implications for the development of percussive traditions. *PLOS ONE*, 9(11), Article e113567.
- Renfrew, C. (2004). Towards a theory of material engagement. In E. DeMarrais, C. Gosden, & C. Renfrew (Eds.), *Rethinking materiality: The engagement of mind with the material world* (pp. 23–32). McDonald Institute for Archaeological Research.
- Rietveld, E., & Kiverstein, J. (2014). A rich landscape of affordances. *Ecological Psychology*, 26, 325–352.
- Roche, H. (2005). From simple flaking to shaping: Stone knapping evolution among early hominins. In V. Roux, & B. Bril (Eds.), *Stone knapping: The necessary conditions for a uniquely hominin behaviour* (pp. 35–48). McDonald Institute for Archaeological Research.
- Roux, V., & Bril, B. (2005a). General introduction: A dynamic systems framework for studying a uniquely hominin behavior. In V. Roux, & B. Bril (Eds.), *Stone knapping: The necessary conditions for a uniquely hominin behavior* (pp. 1–18). The McDonald Institute for Archaeological Research.
- Roux, V., & Bril, B. (Eds.). (2005b). *Stone knapping: The necessary conditions for a uniquely hominin behaviour*. The McDonald Institute for Archaeological Research.
- Roux, V., Bril, B., & Dietrich, G. (1995). Skills and learning difficulties involved in stone knapping: The case of stone-bead knapping in Khambhat, India. *World Archaeology*, 27(1), 63–87.
- Roux, V., & David, E. (2005). Planning abilities as a dynamic perceptual-motor skill: An actualistic study of different levels of expertise involved in stone knapping. In V. Roux, & B. Bril (Eds.), *Stone knapping: The necessary conditions for a uniquely hominin behavior* (pp. 91–108). The McDonald Institute for Archaeological Research.
- Rowlands, M. (2009). Extended cognition and the mark of the cognitive. *Philosophical Psychology*, 22(1), 1–19.
- Sennett, R. (2008). *The craftsman*. Yale University Press.
- Sharon, G. (2008). The impact of raw material on Acheulian large flake production. *Journal of Archaeological Science*, 35(5), 1329–1344.
- Shea, J. J. (2015). Making and using stone tools: Advice for learners and teachers and insights for archaeologists. *Lithic Technology*, 40, 231–248.
- Sheets-Johnstone, M. (1998). *The primacy of movement*. John Benjamins.

- Shipton, C., & Clarkson, C. (2015a). Flake scar density and handaxe reduction intensity. *Journal of Archaeological Science: Reports*, 2, 169–175.
- Shipton, C., & Clarkson, C. (2015b). Handaxe reduction and its influence on shape: An experimental test and archaeological case study. *Journal of Archaeological Science: Reports*, 3, 408–419.
- Shipton, C., Clarkson, C., & Cobden, R. (2019). Were Acheulean bifaces deliberately made symmetrical? Archaeological and experimental evidence. *Cambridge Archaeological Journal*, 29(1), 65–79.
- Stiegler, B. (1998). *Technics and time, 1: The fault of epimetheus*. Stanford University Press.
- Stout, D. (2002). Skill and cognition in stone tool production: An ethnographic case study from Irian Jaya. *Current Anthropology*, 43, 693–722.
- Stout, D. (2011). Stone toolmaking and the evolution of human culture and cognition. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1567), 1050–1059.
- Stout, D. (2015). Cognitive demands of lower Paleolithic toolmaking. *PLOS ONE*, 10(4), Article e0121804. <https://doi.org/10.1371/journal.pone.0121804>
- Stout, D., Apel, J., Commander, J., & Roberts, M. (2014). Late Acheulean technology and cognition at Boxgrove, UK. *Journal of Archaeological Science*, 41, 576–590.
- Stout, D., & Chaminade, T. (2007). The evolutionary neuroscience of tool making. *Neuropsychologia*, 45, 1091–1100.
- Stout, D., Toth, N., Schick, K., & Chaminade, T. (2008). Neural correlates of Early Stone Age toolmaking: Technology, language and cognition in human evolution. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363, 1939–1949.
- Vaesen, K. (2012). The cognitive bases of human tool use. *Behavioral and Brain Sciences*, 35(4), 203–218.
- White, M. J. (1995). Raw materials and biface variability in southern Britain: A preliminary examination. *Lithics*, 15, 1–20.
- Whiten, A. (2015). Experimental studies illuminate the cultural transmission of percussive technologies in Homo and Pan. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1682), 20140359.
- 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., & Gowlett, J. A. J. (2018). The handaxe reconsidered. *Evolutionary Anthropology: Issues, News, and Reviews*, 27(1), 21–29.
- Yarrow, K., Brown, P., & Krakauer, J. W. (2009). Inside the brain of an elite athlete: The neural processes that support high achievement in sports. *Nature Reviews Neuroscience*, 10(8), 585–596.

About the Author



Lambros Malafouris is Associate Professor of Cognitive Archaeology at the Institute of Archaeology and Tutorial Fellow in Archaeology and Anthropology at Hertford College, University of Oxford. He is PI of HANDMADE: Understanding Creative Gesture in Pottery Making funded through a European Research Council Consolidator Grant (No. 771997; European Union Horizon 2020 programme).