# Lithic typologies should be functional

Radu Iovita

Anthrotopography Laboratory,

Center for the Study of Human Origins,

Department of Anthropology,

New York University, New York, NY, USA

# Abstract

# Complex tool use is one of the defining characteristics of our species, and, because of the good preservation of stone tools (lithics), one of the few which can be studied on the evolutionary time scale. But a quick look at the lithics literature reveals that, although our natural human tendency is to talk about tools in general primarily in terms of their functions (e.g., hammer, knife, etc.), our stone tool typologies contain a mixture of terms relating to guessed function, manufacturing method, and shape. As such, they are entirely unsuitable as units in larger evolutionary analyses. In this paper, I argue based on the psychological literature that function is the primary concept underlying tool concepts in humans and non-human primates. Furthermore, knowing how function is represented and learned in both human and non-human primates offers insights into the reasons why current typologies are insufficient and how they could be constructed to lead to more meaningful analyses. I modify F. Sigaut’s tripartite breakdown of function to correspond to the documented psychological concepts to propose a pragmatic and theoretically palatable system for classifying lithics based on a combination of the causality of the tool’s physical properties, the embeddedness in the user’s biological system, and the recorded use history. These can be objectively defined and gleaned from archaeological specimens through the study of wear traces. I discuss the necessary methodological improvements upon which such a classification method is predicated and consider the necessary investments that must be made to realize its potential.

# Common sense in stone tool classification

Humans are the only creature that studies itself and its origins, and this comes with some unique problems. One of the most difficult ones is drawing the line between “ourselves” and our “previous selves”. In other words, it is easy to be unscientific about where that line lies, especially when talking about the development of the mind. In order to do it, we archaeologists dealing with the earliest periods of human evolution, have to interpret objects that are very simple, and, at the same time, utterly alien to us. Simple, because stone blades and flakes look like objects with which we *do* have experience: one can easily imagine using them to shave, cut, or pierce things – so they, too, must have been shavers, cutters, and piercers. However, in most societies that produce archaeologists, no one grew up making and using stone tools. Even if that were not so, we are not Stone Age people. Paleolithic tools are often produced by hominin species that are, at least morphologically, distinct from us, modern humans, and it is unlikely that the intuitions and experiences of modern human stone tool users would be shared, for example, with Neanderthals (French 2019). For these reasons it is both tempting and dangerous to rely on common sense for our interpretations of what these objects might be and their place within ancient societies.

And yet, the persistent use of common sense for naming and grouping stone tools runs uninterruptedly through the history of Stone Age artifact categorization since Evans (1872). The first major proponent of functional analysis, Sergei Aristarkhovich Semenov, debated (1970) with François Bordes (1967) the virtue of guessing the functions of stone artifacts and then classifying them according to shapes and perceived purposes, as recommended by typologists. Among English-language archaeologists, Robert Dunnell (1978:196) was one of the first to diagnose the root of the problem and outline its consequences:

“The basic question still being asked is whether an object is an ax, or an adze, or an arrowhead. Deceptively, the ‘laws‚ (Fritz and Plog 1970) by which such naming takes place are not archaeological propositions but common cultural conventions of object naming enriched by an acquaintance with the ethnographic record. Thus, sense can be made of the archaeological record without recourse to explicit theory because once objects are named in English, they can be manipulated with common sense.”

Only three years earlier, Clifford Geertz had written a seminal essay describing and defining common sense as a cultural system similar to, but also very different from, religion, science, law and others (Geertz 1975). Unlike other cultural systems that we easily identify as such, common sense has some unique properties that allow it to acquire an air of universality. Geertz ascribes five properties to common sense, “naturalness” (appearing obvious), “practicalness”’ (appearing useful), ’thinness” (appearing to be simple, without complex layers), “immethodicalness”’ (being sometimes contradictory, vague), and “accessibleness” (appearing easy to understand, not requiring specialized knowledge). The first three do not, on first inspection, seem to pose immediate threats to our understanding of ancient tools, but the last two, immethodicalness and accessibleness, allow us to use arbitrary intuition and cultural biases in scientific discourse, almost without noticing it. Even accepting that science itself is a cultural domain (Knorr Cetina 1991; Franklin 1995), albeit one that aspires to universality, there is something particularly disturbing about using common sense in scientific nomenclatures: not only are we using categories that are deceivingly familiar, but doing it feels somehow natural and comfortable, like something anyone can do. This comfort may well be the reason for which, despite frequent calls for changing the way we classify archaeological objects, and especially stone tools (Holdaway and Phillipps 2020; Van Oyen 2013; French 2019; Holdaway and Douglass 2011; Dibble et al. 2017; Bisson 2000; Shea 2014; 2012; Reynolds and Riede 2019; Rezek et al. 2020; Riede et al. 2020), most of the world still uses some version of classification systems developed in the nineteenth century.

In light of these strong incentives to preserve the status quo, what may be needed is, to quote Dunnell once again, “explicit theory,” free of intuition and requiring specialist knowledge. But first, we should investigate what lies at the very bottom of our common-sense ideas about tools.

# Deconstructing tool concepts

As we outlined above, common sense is appealing exactly because it is an informal cultural system that is familiar to many of us (as long as we share the same broad cultural background[[1]](#footnote-2)). We can operate well within it, and it does not take any specialized knowledge to manipulate the concepts. But can we do better than to simply try to evade our historically inappropriate intuition about artifacts? Can we find something even more fundamental, more natural about how we build these common-sense notions of tools? Are there some concepts we can use to build a non-commonsensical, that is, systematic and methodical, yet practical and natural classification for stone tools?

## Humans (and apes!) are pre-programmed “functionalists”

We do not have to search too far to find a reason why we feel so at ease talking about ancient tools as if we had intimate knowledge of them. A cursory review of the psychological literature reveals that tools occupy a special place in human cognition. This fact was already known from the first clinical studies documenting apraxia in patients with brain damage (Damasio et al. 2004; 1996). This capacity for categorizing and naming tools appears fairly early in development. From the age of three, children are capable of distinguishing artifacts from other object domains (Gelman 2013). From then on, they tend to rely more on function than form to categorize them. After the age of six, children and adults believe the use intended by the tool’s creator or designer (designer intended function, DIF) determines an artifact’s function (Matan and Carey 2001; DiYanni and Kelemen 2008). Psychologists call this strong tendency the Design Stance[[2]](#footnote-3) (Dennett 1987; 1990; Kelemen and Carey 2007). Interestingly, children younger than four to six years are more sensitive to affordances (use possibilities arising from an object’s shape or physical properties, (Gibson 1979)). This can cause them to change their classification of an artifact following an observed change in the way the artifact is used, whereas adults and older children will usually stick with the DIF. For example, in Matan and Carey’s experiments, the younger children were more likely to say that a teapot used to water plants was a watering can than those who were six years old or older. We will soon see why this is relevant to human evolution.

Given that we are interested in the use of tools in human evolution, we must ask two questions about the design stance: 1) does it generalize cross-culturally among human groups, and 2) does it generalize to our closest ape relatives? In other words, we have to make sure that our intuition that the bias towards the artifact’s *original* use is universal is not an illusion caused by our own WEIRD (Western, Educated, Industrialized, Rich, Democratic (Henrich, Heine, and Norenzayan 2010)) cultural context. In particular, the concept of *bricolage*, introduced by Lévi-Strauss in *La pensée sauvage* (1962)has been very influential in understanding the difference in attitudes toward technology between hunter-gatherer and industrialized people. Whereas the latter live in societies where almost all tools are purpose-built, often at industrial scales, and commercial forces create single-purpose artifacts all the time (e.g., selfie-sticks and nose-hair trimmers), *bricoleurs* (Fr. “handymen”) improvise based on whatever materials lie at hand to solve technical tasks, thereby frequently repurposing artifacts. Therefore, we might expect that WEIRD common sense about tools having *original purposes* might be culturally determined by a specialized manufacturing industry. But do *bricoleurs* also, like WEIRD children younger than six, and in contrast to WEIRD adults, have a pragmatic conception of artifact function (i.e., one that is partly determined by context)?

To answer this question, Barrett and colleagues (2008) carried out modified versions of Matan and Carey’s (2001) experiments with the Shuar, members of a small hunter-horticultural society from the Amazonian Ecuador. The Shuar have a relative low number of formal tools, all handmade, making them a good example of *bricoleurs*. The subjects were asked to determine the function of a series of repurposed artifacts. They needed to decide, for example, if a net made of string and used for fishing, then later hung up between trees and used as a hammock was *really* a fishing net or *really* a hammock. To the researchers’ surprise, the Shuar also preferred the original, DIF (in this particular case, the fishing net), adding further support for the universality of the design stance.

There is considerable debate about why the design stance exists in humans, more specifically, about the extent to which essences and pragmatics determine people’s reliance on DIF to classify artifacts (Chaigneau, Puebla, and Canessa 2016). What is clear and should suffice for our analysis here, is that functions tend to be fixed by experience, a phenomenon called ‘Functional Fixedness’ (Duncker and Lees 1945; Adamson 1952) and documented in a number of studies on WEIRD adults and children alike. Functional fixedness had likewise been demonstrated to play a role in the Shuar’s conception of artifacts in a previous study (German and Barrett 2005), and recent work has shown that apes are probably affected by it as well (Hanus et al. 2011; Ebel, Völter, and Call 2021).

## Causal mechanical interactions are fundamental to the functional understanding of tools

If function is fundamental to our (and our primate cousins’) conceptualization of tools, and if experience largely fixes that function in our brains, what does that experience consist of? How do we learn tool functions, or, more specifically, what aspects of tool use do subjects pay most attention to when deciding an object’s function?

The easiest way to think of a (simple) tool is as an extension or modification of a body part with/through which an animal experiences the environment. Thus, a hammer amplifies the pounding action of a fist, a knife transfers the cleaving action of the teeth to the hand, and so on. Intuitions in this direction have a long history in the philosophy of technology (Loeve, Guchet, and Bensaude Vincent 2018). The German philosopher of technology Ernst Kapp (1877), possibly elaborating a concept already formulated by Aristotle, coined the term “organ projection” for the idea that (“primitive”) tools are extensions of the physical body, and especially of the hand. In his 1907 work *L’évolution créatrice,* Henri Bergson also wrote of organs as being either internal or external to the body (Bergson, Worms, and François 2013). Perhaps more familiar to Anglophone archaeologists is Leslie White’s (1959) perspective on culture itself as an extrasomatic system of adaptation. Likewise, several archaeologists have suggested that early stone tools took on the biological function of teeth (Schick and Toth 1993; Shea 2017).

But do these theories have a basis in neurophysiology, and do they apply to non-human primates, as well? In answering these questions about experience, we must look at two cases, namely the case of individual experimentation with tools and that of social learning of how to use them, be it through passive observation or active teaching or demonstration. This is necessary because it has been repeatedly shown that apes learn tool-using behaviors through individual experience rather than copying others’ actions (Tennie, Call, and Tomasello 2009).

We know that great apes, in contrast to monkeys, have a predilection for tool use and investigate objects spontaneously in order to use them as tools (Tomasello and Call 1997; Herrmann, Wobber, and Call 2008). They are able to select tools in terms of the physical properties relevant to the task at hand. This includes, for example, the rigidity of tools used for extending one’s reach (Manrique, Gross, and Call 2010) and the hardness and weight of nutcracking hammers (Sirianni, Mundry, and Boesch 2015). There is some evidence that early Oldowan hominins also chose stone raw materials for their stone flake tools based on their durability (Braun et al. 2009), so it is reasonable to assume this was part of the last common ancestor’s technological repertoire.

Moreover, it appears that both humans and animals incorporate tools into unconscious representations of their own bodies, the so-called Body Schema (Maravita and Iriki 2004; Cardinali et al. 2012). For instance, studies on Japanese macaques (Iriki, Tanaka, and Iwamura 1996) taught to use rakes to retrieve food located at a distance show that their prefrontal visual receptive field neurons responded to stimuli located at the end of the rake after using it, but not while passively holding it. The researchers interpreted this to mean that the monkeys temporarily updated the representation of their limb to incorporate the tool. However, the validity of the results is unclear, because the macaques did not spontaneously use the rakes in these experiments, but were taught to use them by the researchers. Nevertheless, subsequent studies in chimpanzees, which are known to use tools spontaneously, have shown some of these neurophysiological effects as well (Povinelli, Reaux, and Frey 2010). However, rather than testing the extension of peripersonal (nearby) space with a reaching tool, the researchers examined the use of a tool to avoid contact between the hand and an aversive object (that had properties known to be unpleasant to chimpanzees, such as being furry or having eyes) already located within peripersonal space. This suggests that, rather than a tool wholly remapping the representation of the limb, representations of both are maintained, so as to foster the use of a tool in hazardous situations. Povinelli et al. even propose that this particular scenario might lie at the base of tool use. It must be said, however, that any tool user has to maintain some aspects of sensory feeling of the end-effector on a tool, or else they would not be able to judge success in its use (Miller et al. 2018).

Key to both the human and non-human primate neurocognitive studies is the element of action: this projection of the body must *do something* to the environment to be incorporated into the Body Schema. Here, apes and humans learn the use of a tool differently. The great apes copy action *outcomes* by experimenting with tools till they obtain the desired result (either self-discovered or shown by demonstration) (Tomasello and Call 1997; Tennie, Call, and Tomasello 2009). That still means that an object must perform some kind of action on the environment to be recognized as a tool. Humans can emulate, but they also copy the gesture used to move the tool (motor action). In human subjects, observing an action activates a brain network similar to the one activated during its execution, a phenomenon called motor resonance (Uithol et al. 2011). However, any action can be broken down into several components that involve different levels of cognition. A back-and-forth movement of the arm holding an unseen tool could be using a knife or an eraser (Reynaud et al. 2019). In fact, Reynaud et al. (2019) review the literature and conclude that, in humans, understanding that something is a tool involves understanding causal properties of *the tool-object interaction*, which is codified in what they call the “tool observation network,” activated when human subjects watch a tool action, and distinct from motor resonance.

To sum up these observations, we can say that Kapp’s concept of “organ projection” can serve as a heuristic for what likely includes the majority of simple Paleolithic tools. Significantly, these findings generalize, at least partially, to non-human primates. Therefore, a comprehensive reconstruction of early tool use involves paying attention to the causal properties of the tool-object interaction and the tool’s embeddedness in the user’s body.

# Implications for archaeology

The observations described above have important implications for how we conduct day-to-day business in archaeological classification. We have seen that function lies at the basis of understanding tools and that this is likely to have been the case for the entirety of the history of our lineage. We will now see how this explains why it is so natural for us to classify archaeological implements in such unhelpful ways, and how we *should* do it so that our typologies fit notions likely to also apply to hominins’ understanding of their own tools.

## Understanding the archaeologist: from the design stance to manufacturing technique

The archaeologist is, just like any other ape, an inveterate functionalist, only that, being also human, she is likely to also have DIF in mind. Faced with a collection of broken bits of stone, she will first grab the ones that are most similar to a basic tool like a knife or a razor (these are, as mentioned in the introduction, largely culturally-determined (and time-dependent) commonsensical names of objects in the archaeologist’s vernacular). These archaeological objects will get a name that corresponds to that DIF (knife, scraper, etc.). The rest, which defy the archaeologist’s experience, undergo a more complex thought process: using a combination of the design stance (attributing the essence of tools to an original designer intended function (DIF) and an overreliance on common sense, our fictitious archaeologist shifts focus from determining the designer-intended function the design itself. As Dunnell (1978) so aptly put it, if an object has an unknown function, we can use common sense to infer what action it might *best be suited* to perform (using common sense), and then focus on the design attributes.

We have seen how, roughly after the age of six, humans tend to rely on form to guess the DIF of an artifact. This works as long as the form is not too strange (for instance, in an experiment, children did not ascribe the ‘boat’ function to a rubber ball pulled by dolphins and using a suction cup as an anchor, despite its purpose being defined as a carrier of people over water (Malt and Johnson 1992)). Relying on shape to infer past function then could therefore lead to incomplete results if the form-function relationship is unfamiliar. For example, when looking for potential projectile tips, archaeologists still frequently restrict samples to “pointy” flakes and blades, even though transverse/cutting arrowheads have been known for a long time (e.g., Rust 1943), a point also made by Semenov (1970).

If the guesswork becomes too difficult (i.e., if the shape is too unfamiliar), there is a tendency to shift focus from the shape itself to how the object was made, because tools *must have been good for something*, whatever that may be (‘expedient’ flakes are often considered ‘waste’). This is how typologies end up mixing tools with obvious functional attributions (scrapers, burins, etc.) with those determined by the method of their manufacture (bifaces, Levallois flakes, Krukowski micro-burins, backed ‘pieces,’ etc.), and those that are simply shape descriptions (‘limaces,’ ‘trapezes’) and, finally, those that are shape descriptions with implied functions (‘points’) (see Figure 1 below for a dissection of the Bordes typology (1961)).



Figure 1. François Bordes's typology (1961) by definitional criterion, manufacture, function, or shape.

We are thus overplaying our cards in two ways: first, by assuming a DIF using analogy in an inappropriate way with the ‘easy’ pieces, and second, by relegating DIF to secondary importance and turning to manufacture as a classification principle with the ‘difficult’ ones. This infelicitous result is thus a by-product of the embarrassing condition of not knowing – or not caring enough about – the functional aspect of Paleolithic objects.

## Understanding ancient hominins: switching to the animal view

Even though we may have gained a certain amount of sympathy for ourselves as prisoners of our psychology, we still cannot leave things as they are. To fight the tyranny of common sense, we must de-familiarize our terminology. Animal researchers do not have the luxury of common sense when studying tool using behaviors, and we archaeologists might learn something from them. Beck provides just such a useful definition of tool use from animal studies (Beck 1980; Shumaker, Walkup, and Beck 2011:29):

the external employment of an unattached or manipulable attached environmental object to alter more efficiently the form, position, or condition of another object, another organism, or the user itself, when the user holds and directly manipulates the tool during or prior to use and is responsible for the proper and effective orientation of the tool.

This definition suffices for the majority of tools that are used by hunter-gatherers in the ethnographic literature and likely during prehistory and avoids some of the issues that appear in the later anthropology of technology literature that encompasses the industrial and post-industrial eras.

Following the discussion above, I split the vernacular (and become ambiguously technical) term *function* into three separate parts, each corresponding to a different concept taken from the psychology and animal behavior literature: *structural function*, *operation*, and *designer intended function (DIF)*. The tripartite terminology used by Sigaut in his works on artifacts (partly based on Paillard’s work (1976) on plasticity in neurobiology) and especially on his elaborated example of the knife (Sigaut 1991) is not exactly the same, but similar enough that to not compare and ultimately draw from both of them would be a missed opportunity (see below Table 1).

The term *structural function* proposed hereis thus a marriage between the biological concept of function (as derived from the body schema that includes embedded artifacts) and Sigaut’s *structure*, which, among several other attributes, describes the interface between the tool and its environment. This level can be applied to all analyses of tools, regardless of the species using it and its cognitive capacities. As mentioned above, apes tend to copy the result of tool actions they observe, and therefore try to replicate the causal properties of the tool-environment interaction using their own abilities. This is exactly what the notion of structural function tries to capture.

The next level, *operation*, relates to learning the function of artifacts from others (in humans, by copying the use gesture) and representing them through their motor associations, which, established above, determine learning about tools. Because apes do not copy gestures, the degree to which the operation of tools may or may not be standardized could be an interesting avenue for distinguishing ‘ape use’ from ‘human use’ of similar tools. This term corresponds fairly well to Sigaut’s *fonctionnement*, which does not translate well (the English gerund ‘functioning,’ used by Rots and Plisson (2014), is grammatically and semantically ambiguous).

Finally, both Sigaut’s *fonction* and the French and English vernacular *fonction/function* are replaced here with *designer-intended function* (DIF) to reflect better the notion derived from the psychological literature. As outlined above, it applies to both human and non-human primates.

The terminology proposed here is a compromise among the needs of several different fields that do not necessarily talk to each other: 1) to express the same thing for humans and for animals (at least hominoid apes), 2) to reflect actual, falsifiable concepts from experimental psychology, and 3) to correspond to studiable attributes of archaeological tools. It is for these reason that I did not simply translate Sigaut’s terminology: Fr. *structure* is too tightly connected with the notion of artifact form[[3]](#footnote-4) and his use of *fonction* to refer to DIF aligns the scientific terminology too closely to the common-sense vernacular. By asking ourselves what an artifact looks like and what it might have been used for, it is very easy to ignore *fonctionnement*, continuing our daily business of describing shapes and how people made them.

The new terms are also ranked as far as the degree of underdetermination by available data. We have a good idea of how to reconstruct the causal relationships between tool and body and tool and workpiece using physical and chemical scientific principles which can be assumed to be uniformitarian (Holdaway and Douglass 2011; Dibble et al. 2017; Iovita et al. 2021). In the next section, I work out an example showing the building blocks for reconstructing the operation of tools from the same use traces, although this ultimately depends on the complexity of the tool and the amount and quality of available experimental evidence. Finally, the gold standard, and the likely emic connection between our understanding of technology and that of ancient people, purpose, that is, DIF, is the most underdetermined of them all. This is because proving intention forensically is underdetermined even for recent crime investigations, let alone for discarded ancient stone tools, which undergo various modifications, both intentional and post-depositional. The equifinality of intention is illustrated even in cases where we can watch the action happening live, as in the famous “Dr. Jekyll and Mr. Hyde scenario” offered by Jacob and Jeannerod (2005): is the scalpel the character grabs a murder weapon or a physician’s tool?

Table 1. Proposed nomenclature for a comprehensive functional analysis of prehistoric artifacts, that takes into account concepts from psychology and animal behaviour.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Term***  *(Sigaut equivalent)* | ***What does it mean?*** | ***Psycho-logical concept*** | ***Typical use traces*** | ***Under-determined?*** |
| ***Structural Function***  *Structure (Sigaut)* | Causal relationship between body, tool (including its parts), and workpiece (e.g., shaving vs. scraping) | Body schema, tool-object interaction | -Location of wear (relative to whole tool)  -Hafting wear & residues  -Fatigue wear | Weakly |
| ***Operation***  *Fonction-nement (Sigaut)* | Gesture used to carry out action | Motor learning | -Striations  -Location of wear (within working part) | Somewhat |
| ***Designer Intended Function (DIF)***  *Fonction (Sigaut)* | What is it ‘for’? E.g., peeling *wood*, sawing *antler*, etc. | Designer intended Function (DIF), functional fixedness | -all of the above + polishes indicative of worked material | Strongly |

# A worked example

The importance accorded by humans to both tool-using gestures and to the causality of the tool-workpiece interaction (especially in learning what a tool is) give us a perfect framework for building a meaningful notion of function in prehistory using microscopic use-traces. The simple reason why that is so is because use-traces are the direct result of physical processes that ensue during tool use. To illustrate how such an approach might work, I turn to the example of endscrapers. This tool type appears in virtually all typologies defined as having a scraper edge at the distal end of an (usually) elongated blank. The name implies the causal interaction with the workpiece (its function, in the present terminology): removing a substance or layer of the workpiece (one scrapes something *off* something else) by pushing the edge transversally across it. It is different from shaving or carving by virtue of not removing a significant part of the workpiece, but only a superficial part or layer of it (like the peel, bark, scales, etc.) or something that had previously been added to it (like paint on a boat, or ice on car windows).

Although most endscrapers look macroscopically similar to each other, ethnographic studies have shown an impressive variety in how they are used motorically and, therefore, within various hafting configurations (Weedman 2006; Beyries and Rots 2010; Nissen and Dittemore 1974). This implies entirely different *structural functions,* but also modes of *operation* which are coupled with the former. Just like Sigaut’s knives (some of which are operated with surprising movements, such as by foot), endscraper bits can be located at the end of hafts, transversal to them, or in the middle of the handle; they can be pulled or pushed, with one or two hands, and, of course, using a variety of working angles. The dynamic and kinematic parameters of the motion are integral to learning how to correctly use the tool (of which the lithic ‘endscraper’ is only a part). To a certain degree, they are dictated by and optimized within the constraints of the haft’s construction, such that the task will not be as successful as it could be without the correct gesture. Among humans, we can assume that most of these gestures are culturally transmitted, therefore their reconstruction often offers a window into an ancient cultural tradition. However, one can imagine that many ‘correct use’ movements could also be reinvented by a naïve user, given enough experience using the tool, so this kind of analysis is not restricted to recent humans where we can assume cumulative culture (Tennie, Call, and Tomasello 2009).

Because the aforementioned improvements to the tool’s design are often added incrementally by individual craftspeople, understanding why a tool is constructed the way it is involves careful monitoring of expert users to observe which parameters are involved in the task. It cannot be immediately understood by inspection of the archaeological pieces. Although it has long been known that endscrapers can be used in either a pushed or pulled gesture (e.g., Sergei Aristarhovich Semenov 1957, 112), in our instrumented hide scraping experiments using pushing and pulling gestures, we realized that, due to the acuter working angle, the pushing gesture yielded more shear force, thus scraping off more material per stroke, but the haft configuration associated with it required more torque to stabilize the tool (Pfleging et al. 2015; Pfleging 2019). Therefore, the more efficient hafting configuration (with the tool jutting out of the distal tip of the haft) was sub-optimally designed for the movement we employed, because it required more energy to hold and the user became tired more quickly. Looking at the ethnographic examples known around the world, there are a few that combine the advantages of a pushing gesture with a more ergonomic haft. There are two possibilities, one is to use two hands (the Chukchi solution (Beyries and Rots 2010)) and the one-handed, so-called ‘pistol-grip’ used in Alaskan hide scrapers (Nissen and Dittemore 1974). The fact that both of these solutions optimize tool stabilization in a task where failure (poking a hole in the hide) is the result of failing to stabilize the tool suggests that people are conscious of entire causal chains and making deliberate engineering decisions, although the establishment of solutions obtained by trial-and-error cannot be ruled out entirely.

How far up this chain of causation we can go using contemporary use wear analysis remains debatable. Several studies have tried to employ use wear traces to go beyond identifying basic linear gestures. Takase (2010b; 2012) studied several types of ethnographic Siberian and Japanese scrapers and was able to reconstruct the working angles of archaeological scrapers by measuring them on micrographs of the endscraper bits in profile (Takase 2010a). Beyries and colleagues (Gauvrit Roux and Beyries 2018; Beyries and Rots 2010) devised a similar protocol based also on the location and spread of traces on the working edges, which is also currently being blind-tested (Rodriguez, Pfleging, et al. 2022). At the moment, reconstructing gestures from use-wear traces alone is still very difficult, especially with hafted tools, because it is not sufficient to understand which part was hafted, but also what kind of forces were transmitted by the haft to the stone bit. Moreover, reconstructing the exact hafting arrangement depends on the spatial distribution of traces, such as notches, bright friction spots, and striations, among others (Stordeur 1987 and references therein; Rots 2003). The more complex the history of the artifact (including, for instance, re-hafting of the same piece after breakage or resharpening), the more superimposed such traces can be, making a final interpretation and reconstruction uncertain or simply very time-consuming. However, the initial recording of active edges and general motion direction of the active edge (transversal v. longitudinal) remains one of the easiest and most robust within use-wear studies (Sergei Aristarhovich Semenov 1957; Odell and Odell-Vereecken 1980) and requires the least expensive equipment, therefore constituting a very solid starting point for any lithic archaeologist. Likewise, a number of studies have recently focused on the mode of delivery of penetration weapons (Iovita et al. 2016; Hutchings 2011; Coppe et al. 2019; Rots, Coppe, and Conard 2022), which largely depends on the magnitude and direction of forces opposed to the weapon tip.

Hand-held tools (probably making up the majority of all stone tools in human evolution) offer a different type of challenge. Although figuring out the working edge is relatively easy, the lack of a haft and the flexibility of the human hand, and the differences in the hand anatomy across populations (e.g., Karakostis et al. 2018) make for a large number of possibilities that have to be tried out experimentally. Some studies have tried to guess using common sense (Key and Dunmore 2018), but much more needs to be done. In particular, it remains difficult to locate and measure the exact location of the application of forces from the forelimb complex and their subsequent transfer to the effector (the tool’s active part). On the other hand, the reward of reconstructing most of the elements of artifact function (function within the body schema and operation, and finally, purpose) is nearer than in the hafted case, as the tool itself (meaning the active part and its articulation to the body) is quasi-completely preserved.

# Function at the aggregate level

Several recent papers have pointed out that there are major issues with the way we currently organize our knowledge about stone tools at the aggregate level (Dibble et al. 2017; Rezek et al. 2020), and that extracting evolutionarily relevant information from them requires a methodological rethinking (Iovita et al. 2021). One of the major thrusts of these papers was the argument that aggregates of stone tools that we call ‘sites’ and ‘assemblages’ are arbitrary and most likely do not reflect ancient realities, but rather peculiarities of accumulation. In particular, the fragmented character of ancient intentionality poses a very difficult challenge to studies of *chaînes opératoires* (Turq et al. 2013). What is the *real* method or recipe for making an object if we do not even know how *many people* were involved in bringing it to the form in which it entered the archaeological record? How long did it take, and over how many individual sessions was the work distributed? What even *is* such an object?

We can start answering that question by *always* starting with a functional analysis. We know that the best approximation of tool representation comes from experience and historical use data – what an object is, is what it *has been*. Of course individual tools are not exempt from the same fragmentation of intentionality mentioned above (Lemorini et al. 2015), but there are important differences. Unlike a flake detachment, use wear traces are not usually observable unless actions were repeated long enough to form striations, polishes, etc. While some of these do reflect involuntary movements, such as the wobbling of a tool in the haft (Rots 2010), the majority of what traceologists study are by-products of both repeated *and* intentional action. By studying wear patterns at a large enough scale, and by associating them with morphological and manufacturing information, we might be able to detect regularities in the techniques used for making tools for a specific purpose or discarding them at specific location, or even recycling them in a particular way. Although the emergence critique of assemblages still poses important problems, and we cannot expect to really test Binford and Binford’s functional hypothesis for Mousterian variability (1966) even if we collect functional information from every Middle Paleolithic tool, interpretable patterns may still emerge (Akoshima 1993; Akoshima and Kanomata 2015). Surprising discontinuities or discrepancies might then really document ad-hoc uses or instances of ancient *bricolage*, or even the arrival of a different population that recycles tools found on the landscape (Coco, Holdaway, and Iovita 2020). Either way, we will be moving toward a much richer understanding of the Paleolithic record.

# Conclusions

In the previous pages, I argued that function is the most important property of artifacts, and the property we naturally use to classify tools. Moreover, this predilection generalizes to non-human primates and can be used to understand tool concepts independent of higher cognitive domains such as language and culture. Ideas such as the body schema and the tool-object interaction within the learning structure in both human and non-human primates help us identify the relevant forensic parameters for building a more rigorous approach to reconstructing prehistoric tool functions.

It follows from the above demonstration that the issue of figuring out stone tool function on a global scale should be one of the top priorities of Paleolithic archaeology. Indeed, it is almost strange that we are having to discuss it. Yet, unfortunately, only a minority of prehistorians is actively working on the functional aspects of ancient stone tools. We can only assume that this is a result of the known issues within the field of use wear analysis (J. M. Marreiros, Bao, and Bicho 2014), such as that it is labor-intensive, it requires expensive instruments and specialized knowledge that can often only learned within a rigid apprenticeship framework, and even that doubts persist as to its validity as a scientific method, due to issues of reproducibility and ambiguity.

These criticisms are all valid and the reluctance understandable, but it seems that we have little choice but to work to improve the method and democratize it, reduce the costs and introduce quality control in our assessments. As mentioned above, re-building classifications bottom-up, from structural function to operation and finally, to purpose, will allow us to finally relate manufacturing choices that archaeologists already understand so well to intuitive and shared understandings of what stone tools really are. The use of artificial intelligence (e.g., Van Den Dries 1998) is likely to lower the threshold of knowledge and/or experience required to engage in use-wear research. If algorithms can be trained to work with data collected by cheaper instruments, such an approach could also lower the financial investment necessary to acquire the necessary equipment. The publication of experimental reference collections, more and more often mentioned in the literature (e.g., J. Marreiros et al. 2020), will need to become a reality. Eventually, one can only hope that functional analysis will be something *every archaeology student* will be taught to conduct with a fair amount of competence.

However, for all of this to become a reality, our general community of lithic analysts needs to invest massively in collaborative methodological development (and possibly, to reorganize some priorities). It will take us away from interpreting our beloved archaeological stone tools and drawing big evolutionary conclusions from them. This will inevitably mean unpacking some of the experimental protocols that generate our reference collections (J. M. Marreiros, Pereira, and Iovita 2020; J. Marreiros et al. 2020). It might mean years spent returning to debating the virtues and pitfalls of using various molding compounds (Banks and Kay 2003; Macdonald, Harman, and Evans 2018) and cleaning methods (Plisson 1983; Adrian A. Evans and Donahue 2005; Pedergnana et al. 2020), microscope apertures (Calandra et al. 2019) and different acquisition software (Calandra 2022; Stemp 2022). We will have to wonder about the basic nature of our units of analysis, such as what creates polishes (e.g., Anderson 1980; Yamada 1993; Ollé and Vergès 2008; Schmidt et al. 2020; Rodriguez, Yanamandra, et al. 2022), and what might destroy them (Levi Sala 1986; Michel, Cnuts, and Rots 2019). We will have to check each other’s work using blind tests (Newcomer, Grace, and Unger-Hamilton 1986; Wadley, Lombard, and Williamson 2004; Rots et al. 2006; Adrian Anthony Evans 2014; Rots et al. 2016) and, at least occasionally, acknowledge defeat. And it will be, at times, intensely boring. However, as Hussain and Soressi (2021:25) recently put it, “basic science entails at least some knowledge ‘banality’.” The alternative – to ignore what stone tools were actually used for – is no longer tenable.

# Acknowledgements

I wish to thank Dan Glotzer (U. Pennsylvania) for orienting me within the psychological literature, especially on children. Likewise, I thank Patrick Schmidt and especially Claudio Tennie (U. Tübingen) for reading two drafts and pointing me to the most recent work on ape learning and tool concepts.

# Conflict of interest

The authors declare that they comply with the PCI rule of having no financial conflicts of interest in relation to the content of the article.

# References

Adamson, Robert E. 1952. “Functional Fixedness as Related to Problem Solving: A Repetition of Three Experiments.” *Journal of Experimental Psychology* 44 (4): 288.

Akoshima, Kaoru. 1993. “Microwear Patterns and Distributional Variability in Terminal Palaeolithic Site Structure.” Ph.D., United States -- New Mexico: The University of New Mexico. https://www.proquest.com/pqdtglobal/docview/304080850/abstract/56BF339012274DD0PQ/1.

Akoshima, Kaoru, and Yoshitaka Kanomata. 2015. “Technological Organization and Lithic Microwear Analysis: An Alternative Methodology.” *Journal of Anthropological Archaeology*, Archaeology IS Anthropology: Lewis R. Binford’s Dynamic Contributions to Archaeology Theory and Practice, 38 (June): 17–24. https://doi.org/10.1016/j.jaa.2014.09.003.

Anderson, Patricia C. 1980. “A Testimony of Prehistoric Tasks: Diagnostic Residues on Stone Tool Working Edges.” *World Archaeology* 12 (2): 181–94. https://doi.org/10.1080/00438243.1980.9979791.

Banks, William E, and Marvin Kay. 2003. “High-Resolution Casts for Lithic Use-Wear Analysis.” *Lithic Technology*, 27–34.

Barrett, H. Clark, Stephen Laurence, and Eric Margolis. 2008. “Artifacts and Original Intent: A Cross-Cultural Perspective on the Design Stance.” *Journal of Cognition and Culture* 8 (1–2): 1–22.

Beck, Benjamin B. 1980. *Animal Tool Behavior: The Use and Manufacture of Tools by Animals*. Garland STPM Pub.

Bergson, Henri, Frédéric Worms, and Arnaud François. 2013. *L’évolution créatrice*. Réimpression de la 12 éd. Quadrige. Paris: Presses universitaires de France.

Beyries, Sylvie, and Veerle Rots. 2010. “Méthode de Reconstitution Des Procédés de Traitement Des Peaux En Préhistoire.” *The Magdalenian Household: Unraveling Domesticity*, 269.

Binford, Lewis R., and Sally R. Binford. 1966. “A Preliminary Analysis of Functional Variability in the Mousterian of Levallois Facies.” *American Anthropologist* 68 (2): 238–95.

Bisson, Michael S. 2000. “Nineteenth Century Tools for Twenty-First Century Archaeology? Why the Middle Paleolithic Typology of François Bordes Must Be Replaced.” *Journal of Archaeological Method and Theory* 7 (1): 1–48.

Bordes, François. 1961. *Typologie Du Paléolithique Ancien et Moyen*. Vol. Mémoire 1. Bordeaux: Delmas.

———. 1967. “Considérations Sur La Typologie et Les Techniques Dans Le Paléolithique.” *Quartär* 18: 25–55.

Braun, David R., Thomas Plummer, Joseph V. Ferraro, Peter Ditchfield, and Laura C. Bishop. 2009. “Raw Material Quality and Oldowan Hominin Toolstone Preferences: Evidence from Kanjera South, Kenya.” *Journal of Archaeological Science* 36 (7): 1605–14. https://doi.org/10.1016/j.jas.2009.03.025.

Calandra, Ivan. 2022. “A Workflow for Quality Control in Surface Texture Analysis Applied to Teeth and Tools.” *Journal of Archaeological Science: Reports* 46 (December): 103692. https://doi.org/10.1016/j.jasrep.2022.103692.

Calandra, Ivan, Lisa Schunk, Konstantin Bob, Walter Gneisinger, Antonella Pedergnana, Eduardo Paixao, Andreas Hildebrandt, and Joao Marreiros. 2019. “The Effect of Numerical Aperture on Quantitative Use-Wear Studies and Its Implication on Reproducibility.” *Scientific Reports* 9 (1): 6313. https://doi.org/10.1038/s41598-019-42713-w.

Cardinali, Lucilla, Stéphane Jacobs, Claudio Brozzoli, Francesca Frassinetti, Alice C Roy, and Alessandro Farnè. 2012. “Grab an Object with a Tool and Change Your Body: Tool-Use-Dependent Changes of Body Representation for Action.” *Experimental Brain Research* 218 (2): 259–71. https://doi.org/10.1007/s00221-012-3028-5.

Chaigneau, Sergio E., Guillermo Puebla, and Enrique C. Canessa. 2016. “Why the Designer’s Intended Function Is Central for Proper Function Assignment and Artifact Conceptualization: Essentialist and Normative Accounts.” *Developmental Review* 41 (September): 38–50. https://doi.org/10.1016/j.dr.2016.06.002.

Coco, Emily, Simon Holdaway, and Radu Iovita. 2020. “The Effects of Secondary Recycling on the Technological Character of Lithic Assemblages.” *Journal of Paleolithic Archaeology*. https://doi.org/10.1007/s41982-020-00055-4.

Coppe, J., C. Lepers, V. Clarenne, E. Delaunois, M. Pirlot, and V. Rots. 2019. “Ballistic Study Tackles Kinetic Energy Values of Palaeolithic Weaponry.” *Archaeometry* 61 (4): 933–56. https://doi.org/10.1111/arcm.12452.

Damasio, H, T J Grabowski, D Tranel, R D Hichwa, and A R Damasio. 1996. “A Neural Basis for Lexical Retrieval.” *Nature* 380 (6574): 499–505. https://doi.org/10.1038/380499a0.

Damasio, H, D Tranel, T Grabowski, R Adolphs, and A Damasio. 2004. “Neural Systems behind Word and Concept Retrieval.” *Cognition* 92 (1–2): 179–229. https://doi.org/10.1016/j.cognition.2002.07.001.

Dennett, Daniel C. 1987. *The Intentional Stance*. Cambridge, Mass: MIT Press.

———. 1990. “The Interpretation of Texts, People and Other Artifacts.” *Philosophy and Phenomenological Research* 50: 177–94. https://doi.org/10.2307/2108038.

Dibble, Harold L., Simon J. Holdaway, Sam C. Lin, David R. Braun, Matthew J. Douglass, Radu Iovita, Shannon P. McPherron, Deborah I. Olszewski, and Dennis Sandgathe. 2017. “Major Fallacies Surrounding Stone Artifacts and Assemblages.” *Journal of Archaeological Method and Theory* 24 (3): 813–51. https://doi.org/10.1007/s10816-016-9297-8.

DiYanni, Cara, and Deborah Kelemen. 2008. “Using a Bad Tool with Good Intention: Young Children’s Imitation of Adults’ Questionable Choices.” *Journal of Experimental Child Psychology* 101 (4): 241–61.

Duncker, Karl, and Lynne S. Lees. 1945. “On Problem-Solving.” *Psychological Monographs* 58 (5): i.

Dunnell, Robert C. 1978. “Style and Function: A Fundamental Dichotomy.” *American Antiquity* 4: 192–202.

Ebel, Sonja J., Christoph J. Völter, and Josep Call. 2021. “Prior Experience Mediates the Usage of Food Items as Tools in Great Apes (Pan Paniscus, Pan Troglodytes, Gorilla Gorilla, and Pongo Abelii).” *Journal of Comparative Psychology* 135 (1): 64. https://doi.org/10.1037/com0000236.

Evans, Adrian A., and Randolph E. Donahue. 2005. “The Elemental Chemistry of Lithic Microwear: An Experiment.” *Journal of Archaeological Science* 32 (12): 1733–40. https://doi.org/10.1016/j.jas.2005.06.010.

Evans, Adrian Anthony. 2014. “On the Importance of Blind Testing in Archaeological Science: The Example from Lithic Functional Studies.” *Journal of Archaeological Science* 48 (C): 5–14. https://doi.org/10.1016/j.jas.2013.10.026.

Evans, John. 1872. *The Ancient Stone Implements, Weapons, and Ornaments of Great Britain*. New York: Appleton.

Franklin, Sarah. 1995. “Science as Culture, Cultures of Science.” *Annual Review of Anthropology* 24: 163–84.

French, Jennifer C. 2019. “The Use of Ethnographic Data in Neanderthal Archaeological Research: Recent Trends and Their Interpretative Implications.” *Hunter Gatherer Research* 4 (1): 25–49. https://doi.org/10.3828/hgr.2018.3.

Gauvrit Roux, Eugénie, and Sylvie Beyries. 2018. “Le Travail de La Peau Au Magdalénien Moyen Ancien: Analyse Techno-Fonctionnelle Des Grattoirs de La Marche (Lussac-Les-Châteaux, Vienne).” *Bulletin de La Société Préhistorique Française* 115 (4): 647–76.

Geertz, Clifford. 1975. “Common Sense as a Cultural System.” *The Antioch Review* 33 (1): 5–26. https://doi.org/10.2307/4637616.

Gelman, Susan A. 2013. “Artifacts and Essentialism.” *Review of Philosophy and Psychology* 4 (3): 449–63. https://doi.org/10.1007/s13164-013-0142-7.

German, Tim P., and H. Clark Barrett. 2005. “Functional Fixedness in a Technologically Sparse Culture.” *Psychological Science* 16 (1): 1–5. https://doi.org/10.1111/j.0956-7976.2005.00771.x.

Gibson, James J. 1979. *The Ecological Approach to Visual Perception*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Hanus, Daniel, Natacha Mendes, Claudio Tennie, and Josep Call. 2011. “Comparing the Performances of Apes (Gorilla Gorilla, Pan Troglodytes, Pongo Pygmaeus) and Human Children (Homo Sapiens) in the Floating Peanut Task.” *PLOS ONE* 6 (6): e19555. https://doi.org/10.1371/journal.pone.0019555.

Henrich, Joseph, Steven J Heine, and Ara Norenzayan. 2010. “The Weirdest People in the World?” *Behavioral and Brain Sciences* 33 (2–3): 1–75. https://doi.org/10.1017/S0140525X0999152X.

Herrmann, Esther, Victoria Wobber, and Josep Call. 2008. “Great Apes’ (<em>Pan Troglodytes, Pan Paniscus, Gorilla Gorilla, Pongo Pygmaeus</Em>) Understanding of Tool Functional Properties after Limited Experience.” *Journal of Comparative Psychology* 122 (2): 220. https://doi.org/10.1037/0735-7036.122.2.220.

Holdaway, Simon, and Matthew Douglass. 2011. “A Twenty-First Century Archaeology of Stone Artifacts.” *Journal of Archaeological Method and Theory* 19 (1): 101–31. https://doi.org/10.1007/s10816-011-9103-6.

Holdaway, Simon, and Rebecca Phillipps. 2020. “Artefact Categories, Artefact Assemblages and Ontological Alterity.” *Cambridge Archaeological Journal*, September, 1–18. https://doi.org/10.1017/S095977432000030X.

Hussain, Shumon Tobias, and Marie Soressi. 2021. “The Technological Condition of Human Evolution: Lithic Studies as Basic Science.” *Journal of Paleolithic Archaeology* 4 (3): 25. https://doi.org/10.1007/s41982-021-00098-1.

Hutchings, W Karl. 2011. “Measuring Use-Related Fracture Velocity in Lithic Armatures to Identify Spears, Javelins, Darts, and Arrows.” *Journal of Archaeological Science* 38 (7): 1737–46. https://doi.org/10.1016/j.jas.2011.03.005.

Iovita, Radu, David R. Braun, Matthew J. Douglass, Simon J. Holdaway, Sam C. Lin, Deborah I. Olszewski, and Zeljko Rezek. 2021. “Operationalizing Niche Construction Theory with Stone Tools.” *Evolutionary Anthropology: Issues, News, and Reviews* 30 (1): 28–39. https://doi.org/10.1002/evan.21881.

Iovita, Radu, Holger Schönekeß, Sabine Gaudzinski-Windheuser, and Frank Jäger. 2016. “Identifying Weapon Delivery Systems Using Macrofracture Analysis and Fracture Propagation Velocity: A Controlled Experiment.” In *Multidisciplinary Approaches to the Study of Stone Age Weaponry*, edited by Radu Iovita and Katsuhiro Sano, 13–27. Dordrecht: Springer Netherlands. http://link.springer.com/10.1007/978-94-017-7602-8\_2.

Iriki, Atsushi, Michio Tanaka, and Yoshiaki Iwamura. 1996. “Coding of Modified Body Schema during Tool Use by Macaque Postcentral Neurones.” *NeuroReport* 7 (14): 2325.

Jacob, Pierre, and Marc Jeannerod. 2005. “The Motor Theory of Social Cognition: A Critique.” *Trends in Cognitive Sciences* 9 (1): 21–25. https://doi.org/10.1016/j.tics.2004.11.003.

Kapp, Ernst. 1877. *Grundlinien einer Philosophie der Technik. Zur Entstehungsgesschichte des Kultur aus neuen Gesichtspunkten*. Brunswick: Westermann.

Karakostis, Fotios Alexandros, Gerhard Hotz, Vangelis Tourloukis, and Katerina Harvati. 2018. “Evidence for Precision Grasping in Neandertal Daily Activities.” *Science Advances* 4 (9): eaat2369. https://doi.org/10.1126/sciadv.aat2369.

Kelemen, Deborah, and Susan Carey. 2007. “The Essence of Artifacts: Developing the Design Stance.” *Creations of the Mind: Theories of Artifacts and Their Representation*, 212–30.

Key, Alastair J. M., and Christopher J. Dunmore. 2018. “Manual Restrictions on Palaeolithic Technological Behaviours.” *PeerJ* 6 (August): e5399. https://doi.org/10.7717/peerj.5399.

Knorr Cetina, Karin. 1991. “Epistemic Cultures: Forms of Reason in Science.” *History of Political Economy* 23 (1): 105–22. https://doi.org/10.1215/00182702-23-1-105.

Lemorini, Cristina, Flavia Venditti, Ella Assaf, Yoni Parush, Ran Barkai, and Avi Gopher. 2015. “The Function of Recycled Lithic Items at Late Lower Paleolithic Qesem Cave, Israel: An Overview of the Use-Wear Data.” *Quaternary International*, The Origins of Recycling: A Paleolithic Perspective, 361 (March): 103–12. https://doi.org/10.1016/j.quaint.2014.07.032.

Levi Sala, Irene. 1986. “Use Wear and Post-Depositional Surface Modification: A Word of Caution.” *Journal of Archaeological Science* 13 (3): 229–44.

Lévi-Strauss, Claude. 1962. *La Pensée Sauvage*. Paris: Plon.

Loeve, Sacha, Xavier Guchet, and Bernadette Bensaude Vincent. 2018. *French Philosophy of Technology: Classical Readings and Contemporary Approaches*. Philosophy of Engineering and Technology. Cham: Springer.

Macdonald, Danielle A., Robert Harman, and Adrian A. Evans. 2018. “Replicating Surface Texture: Preliminary Testing of Molding Compound Accuracy for Surface Measurements.” *Journal of Archaeological Science: Reports* 18 (April): 839–46. https://doi.org/10.1016/j.jasrep.2018.02.033.

Malt, Barbara C, and Eric C Johnson. 1992. “Do Artifact Concepts Have Cores?” *Journal of Memory and Language* 31 (2): 195–217. https://doi.org/10.1016/0749-596X(92)90011-L.

Manrique, Héctor Marín, Alexandra Nam-Mi Gross, and Josep Call. 2010. “Great Apes Select Tools on the Basis of Their Rigidity.” *Journal of Experimental Psychology: Animal Behavior Processes* 36 (4): 409–22. https://doi.org/10.1037/a0019296.

Maravita, Angelo, and Atsushi Iriki. 2004. “Tools for the Body (Schema).” *Trends in Cognitive Sciences* 8 (2): 79–86. https://doi.org/10.1016/j.tics.2003.12.008.

Marreiros, João, Ivan Calandra, Walter Gneisinger, Eduardo Paixão, Antonella Pedergnana, and Lisa Schunk. 2020. “Rethinking Use-Wear Analysis and Experimentation as Applied to the Study of Past Hominin Tool Use.” *Journal of Paleolithic Archaeology* 3 (3): 475–502. https://doi.org/10.1007/s41982-020-00058-1.

Marreiros, João Manuel, Juan F. Gibaja Bao, and Nuno Ferreira Bicho. 2014. *Use-Wear and Residue Analysis in Archaeology*. Springer.

Marreiros, João Manuel, Telmo Pereira, and Radu Iovita. 2020. “Controlled Experiments in Lithic Technology and Function.” *Archaeological and Anthropological Sciences* 12 (6): 110. https://doi.org/10.1007/s12520-020-01059-5.

Matan, Adee, and Susan Carey. 2001. “Developmental Changes within the Core of Artifact Concepts.” *Cognition* 78 (1): 1–26. https://doi.org/10.1016/S0010-0277(00)00094-9.

Michel, Marine, Dries Cnuts, and Veerle Rots. 2019. “Freezing In-Sight: The Effect of Frost Cycles on Use-Wear and Residues on Flint Tools.” *Archaeological and Anthropological Sciences* 11 (10): 5423–43. https://doi.org/10.1007/s12520-019-00881-w.

Miller, Luke E., Luca Montroni, Eric Koun, Romeo Salemme, Vincent Hayward, and Alessandro Farnè. 2018. “Sensing with Tools Extends Somatosensory Processing beyond the Body.” *Nature* 561 (7722): 239–42. https://doi.org/10.1038/s41586-018-0460-0.

Newcomer, M., R. Grace, and R. Unger-Hamilton. 1986. “Investigating Microwear Polishes with Blind Tests.” *Journal of Archaeological Science* 13 (3): 203–17. https://doi.org/10.1016/0305-4403(86)90059-2.

Nissen, Karen, and Margaret Dittemore. 1974. “Ethnographic Data and Wear Pattern Analysis: A Study of Socketed Eskimo Scrapers.” *Tebiwa* 17 (1): 67–88.

Odell, George Hamley, and Frieda Odell-Vereecken. 1980. “Verifying the Relationships of Lithic Use Wear Assessments by ‘Blind Tests’: The Low-Power Approach.” *Journal of Field Archaeology* 7 (1): 87–120.

Ollé, Andreu, and Josep Maria Vergès. 2008. “SEM Functional Analysis and the Mechanism of Microwear Formation.” In *“Prehistoric Technology” 40 Years Later: Functional Studies and the Russian Legacy*, edited by Laura Longo and Natalia Skakun, 1783:39–49. BAR International Series. Oxford: Archaeopress.

Paillard, Jacques. 1976. “Réflexions sur l’usage du concept de plasticité en neurobiologie.” *Journal de Psychologie Normale et Pathologique* 1: 33–47.

Pedergnana, Antonella, Ivan Calandra, Konstantin Bob, Walter Gneisinger, Eduardo Paixão, Lisa Schunk, Andreas Hildebrandt, and João Marreiros. 2020. “Evaluating the Microscopic Effect of Brushing Stone Tools as a Cleaning Procedure.” *Quaternary International* 569–570 (December): 263–76. https://doi.org/10.1016/j.quaint.2020.06.031.

Pfleging, Johannes. 2019. “On the Foundations of Robotic Use-Wear Analysis: Improving Archaeological Methods for Artefact Characterization with Robotics Technology.” Doctoral Thesis, ETH Zurich. https://doi.org/10.3929/ethz-b-000403726.

Pfleging, Johannes, Marius Stücheli, Radu Iovita, and Jonas Buchli. 2015. “Dynamic Monitoring Reveals Motor Task Characteristics in Prehistoric Technical Gestures.” *PLoS ONE* 10 (8): e0134570. https://doi.org/10.1371/journal.pone.0134570.

Plisson, Hugues. 1983. “De La Conservation Des Micro-Polis d’utilisation.” *Bulletin de La Société Préhistorique Française. Comptes Rendus Des Séances Mensuelles Paris* 80 (3): 74–77.

Povinelli, Daniel J., James E. Reaux, and Scott H. Frey. 2010. “Chimpanzees’ Context-Dependent Tool Use Provides Evidence for Separable Representations of Hand and Tool Even during Active Use within Peripersonal Space.” *Neuropsychologia* 48 (1): 243–47. https://doi.org/10.1016/j.neuropsychologia.2009.09.010.

Reynaud, Emanuelle, Jordan Navarro, Mathieu Lesourd, and François Osiurak. 2019. “To Watch Is to Work: A Review of NeuroImaging Data on Tool Use Observation Network.” *Neuropsychology Review* 29 (4): 484–97. https://doi.org/10.1007/s11065-019-09418-3.

Reynolds, Natasha, and Felix Riede. 2019. “House of Cards: Cultural Taxonomy and the Study of the European Upper Palaeolithic.” *Antiquity* 93 (371): 1350–58. https://doi.org/10.15184/aqy.2019.49.

Rezek, Zeljko, Simon J. Holdaway, Deborah I. Olszewski, Sam C. Lin, Matthew Douglass, Shannon McPherron, Radu Iovita, David R. Braun, and Dennis Sandgathe. 2020. “Aggregates, Formational Emergence, and the Focus on Practice in Stone Artifact Archaeology.” *Journal of Archaeological Method and Theory*, February. https://doi.org/10.1007/s10816-020-09445-y.

Riede, Felix, Astolfo G.M. Araujo, Michael C. Barton, Knut Andreas Bergsvik, Huw S. Groucutt, Shumon T. Hussain, Javier Fernandez‐Lopez de Pablo, et al. 2020. “Cultural Taxonomies in the Paleolithic—Old Questions, Novel Perspectives.” *Evolutionary Anthropology: Issues, News, and Reviews*, February, evan.21819. https://doi.org/10.1002/evan.21819.

Rodriguez, Alice, Johannes Pfleging, Eugénie Gauvrit Roux, Sylvie Beyries, and Radu Iovita. 2022. “Towards a Modelling of Prehistoric Technical Gestures through Monitored Controlled Experimentation and 3D Optical Profiler.” In *Tracing Social Dynamics, Conference AWRANA 2022*. Barcelone, Spain. https://hal.archives-ouvertes.fr/hal-03636483.

Rodriguez, Alice, Kaushik Yanamandra, Lukasz Witek, Zhong Wang, Rakesh K Behera, and Radu Iovita. 2022. “The Effect of Worked Material Hardness on Stone Tool Wear.” *PloS One* 17 (10): e0276166.

Rots, Veerle. 2003. “Towards an Understanding of Hafting: The Macro- and Microscopic Evidence.” *Antiquity* 77 (298): 805–15.

———. 2010. *Prehension and Hafting Traces on Flint Tools*.

Rots, Veerle, Justun Coppe, and Nicholas J. Conard. 2022. “A Leaf Point Documents Hunting with Spears in the Middle Paleolithic at Hohle Fels, Germany.” *Mitteilungen Der Gesellschaft Für Urgeschichte* 30 (2021): 67–94. https://doi.org/10.51315/mgfu.2021.30004.

Rots, Veerle, Elspeth Hayes, Dries Cnuts, Christian Lepers, and Richard Fullagar. 2016. “Making Sense of Residues on Flaked Stone Artefacts: Learning from Blind Tests.” *PLOS ONE* 11 (3): e0150437. https://doi.org/10.1371/journal.pone.0150437.

Rots, Veerle, L Pirnay, P Pirson, and O Baudoux. 2006. “Blind Tests Shed Light on Possibilities and Limitations for Identifying Stone Tool Prehension and Hafting.” *Journal of Archaeological Science* 33 (7): 935–52.

Rots, Veerle, and Hugues Plisson. 2014. “Projectiles and the Abuse of the Use-Wear Method in a Search for Impact.” *Journal of Archaeological Science* 48 (C): 154–65. https://doi.org/10.1016/j.jas.2013.10.027.

Rust, Alfred. 1943. *Die Alt- Und Mittelsteinzeitlichen Funde von Stellmoor*. Neumünster.

Schick, Kathy D., and Nicholas Toth. 1993. *Making Silent Stones Speak*.

Schmidt, Patrick, Alice Rodriguez, Kaushik Yanamandra, Rakesh K. Behera, and Radu Iovita. 2020. “The Mineralogy and Structure of Use-Wear Polish on Chert.” *Scientific Reports* 10 (1): 21512. https://doi.org/10.1038/s41598-020-78490-0.

Semenov, S A. 1970. “The Forms and Funktions of the Oldest Tools.” *Quartär* 21: 1–20.

Semenov, Sergei Aristarhovich. 1957. *Pervobytnaya Tehnika: Opyt Izucheniya Drevneyshih Orudiy i Izdeliy Po Sledam Raboty [Prehistoric Technology: An Experimental Study of the Oldest Tools and Artefacts from Traces of Manufacture and Wear]*. 54. Moscow: Akademia nauk SSSR.

Shea, John J. 2012. “Lithic Modes A–I: A New Framework for Describing Global-Scale Variation in Stone Tool Technology Illustrated with Evidence from the East Mediterranean Levant.” *Journal of Archaeological Method and Theory* 20 (1): 151–86. https://doi.org/10.1007/s10816-012-9128-5.

Shea, John J. 2014. “Sink the Mousterian? Named Stone Tool Industries (NASTIES) as Obstacles to Investigating Hominin Evolutionary Relationships in the Later Middle Paleolithic Levant.” *Quaternary International*, Lithics of the Late Middle Palaeolithic: Post MIS 5 technological variability and its implications, 350 (November): 169–79. https://doi.org/10.1016/j.quaint.2014.01.024.

———. 2017. *Stone Tools in Human Evolution: Behavioral Differences among Technological Primates*. 1st ed. New York: Cambridge University Press. https://doi.org/10.1017/9781316389355.

Shumaker, Robert W., Kristina R. Walkup, and Benjamin B. Beck. 2011. *Animal Tool Behavior: The Use and Manufacture of Tools by Animals*. Rev. and Updated ed. Baltimore: Johns Hopkins University Press.

Sigaut, François. 1991. “Un Couteau Ne Sert Pas à Couper, Mais En Coupant. Structure, Fonctionnement et Fonction Dans l’analyse Des Objets.” In *25 Ans d’Etudes Technologiques En Préhistoire*, 21–34. Juan-les-Pins: Editions APOCA. http://cat.inist.fr/?aModele=afficheN&cpsidt=6513605.

Sirianni, Giulia, Roger Mundry, and Christophe Boesch. 2015. “When to Choose Which Tool: Multidimensional and Conditional Selection of Nut-Cracking Hammers in Wild Chimpanzees.” *Animal Behaviour* 100 (February): 152–65. https://doi.org/10.1016/j.anbehav.2014.11.022.

Stemp, W. James. 2022. “Ghosts in the Room and Elephants in the Machine: Data Acquisition in Surface Texture Analysis of Stone Tools.” *Lithic Technology* 0 (0): 1–16. https://doi.org/10.1080/01977261.2022.2142391.

Stordeur, Danielle, ed. 1987. *La Main et l’Outil. Manches et Emmanchements Préhistoriques*. Table Ronde C.N.R.S. Tenue à Lyon Du 26 Au 29 Novembre 1984. Lyon: Maison de l’Orient et de la Méditerranée Jean Pouilloux.

Takase, Katsunori. 2010a. “Use Angle and Motional Direction of End Scrapers: A Case Study of the Palaeolithic in Hokkaido, Japan.” *Asian Perspectives* 49 (2): 363–79. https://doi.org/10.1353/asi.2010.0013.

———. 2010b. “Use-Wear Analysis of Stone Tools from the Coast of Karaga Bay, Northeastern Kamchatka, Russia.” *Journal of the Graduate School of Letters, Hokkaido University* 10: 13–25.

———. 2012. “Endscrapers of the Old Koryak Culture: A Case Study in the Kamchatka and Taigonos Peninsulas.” *Journal of the Graduate School of Letters, Hokkaido University* 7: 31–53.

Tennie, Claudio, Josep Call, and Michael Tomasello. 2009. “Ratcheting up the Ratchet: On the Evolution of Cumulative Culture.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 364 (1528): 2405–15. https://doi.org/10.1098/rstb.2009.0052.

Tomasello, Michael, and Josep Call. 1997. *Primate Cognition*. New York: Oxford University Press.

Turq, Alain, Wil Roebroeks, Laurence Bourguignon, and Jean-Philippe Faivre. 2013. “The Fragmented Character of Middle Palaeolithic Stone Tool Technology.” *Journal of Human Evolution*, September, 1–15. https://doi.org/10.1016/j.jhevol.2013.07.014.

Uithol, Sebo, Iris van Rooij, Harold Bekkering, and Pim Haselager. 2011. “Understanding Motor Resonance.” *Social Neuroscience* 6 (4): 388–97. https://doi.org/10.1080/17470919.2011.559129.

Van Den Dries, Monique Henriëtte. 1998. “Archaeology and the Application of Artificial Intelligence: Case-Studies on Use-Wear Analysis of Prehistoric Flint Tools.” PhD Thesis, Leiden: Leiden University.

Van Oyen, Astrid. 2013. “Towards a Post-Colonial Artefact Analysis.” *Archaeological Dialogues* 20 (1): 81–107.

Wadley, Lyn, Marlize Lombard, and Bonny S. Williamson. 2004. “The First Residue Analysis Blind Tests: Results and Lessons Learnt.” *Journal of Archaeological Science* 31 (11): 1491–1501.

Weedman, Kathryn J. 2006. “An Ethnoarchaeological Study of Hafting and Stone Tool Diversity among the Gamo of Ethiopia.” *Journal of Archaeological Method and Theory* 13 (3): 188–237. https://doi.org/10.1007/s10816-006-9010-4.

White, Leslie A. 1959. “The Concept of Culture.” *American Anthropologist* 61 (2): 227–51.

Yamada, Shoh. 1993. “The Formation Process of Use-Wear Polishes.” In *Traces et Fonction: Les Gestes Retrouvés*, edited by Patricia C. Anderson, Sylvie Beyries, Marcel Otte, and Hugues Plisson, 50:433–45. E.R.A.U.L. Liège: Université de Liège.

1. It seems reasonable to assume that archaeologists, even though they may come from different countries and speak different languages, are nevertheless scientists living in an industrial age and exposed to a global material culture that implies a shared set of intuitions about artifacts. [↑](#footnote-ref-2)
2. Although Dennett coined the term, he used to stress that the designer’s intended purpose was irrelevant to the object’s current function. [↑](#footnote-ref-3)
3. The sentiment is, however, the same as the one expressed here: “Il n'y a pas de rapports directs entre forme (ou structure) et fonction. Ils n'existent que médiatisés par le fonctionnement. Vouloir aller directement de la forme à la fonction (ou l'inverse), c'est s'exposer presque fatalement à prendre le fonctionnement pour la fonction et clone à oublier cette dernière.” (Sigaut, 1991, p. 7) [↑](#footnote-ref-4)