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A Radical Embodied Approach to Lower Palaeolithic Spear-making

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It has been argued that spear manufacture at Schöningen around 400 kya required abstract thought and in-depth planning of a kind associated only with fully modern humans. The argument, however, lacks detailed analysis of these cognitive capabilities. In this paper I shall provide such an analysis for the production of spears and show that no qualitatively modern cognitive advancement is required to realize this technology. Situated strategies grounded in re-enacting perceptual simulations are sufficient to obviate the need for any modern form of abstraction in explaining the evidence. This embodied perspective is further radicalized in favor of direct perception, enactivism, and intuitive artifact interaction in order to eliminate any explanatory role for mentalistic plans in both the invention and social transmission of the spear technology. A set of radical embodied cognitive abilities is also sufficient to account for other Acheulean tools, obviating any grounds for qualitative advances in cognition. The enactive integration of stone tools in the perceptual system of *Homo heidelbergensis*, coupled with an increase of information processing capacity, are quite sufficient quantitative augmentations to the capabilities of earlier hominids. The explanations advanced here are nonetheless consistent with a set of classic and innovative theories in cognitive archaeology.

Keywords: cognitive archaeology, embodiment, Schöningen spears

During the middle 1990s a set of incredibly well preserved wooden spears were found at Schöningen, Lower Saxony, Germany (Thieme, 1996, 1997, 1999). Dated at ca 320 kya, in the Lower Palaeolithic (Jöris and Baales, 2003; Urban, Sierralta, and Frechen, 2011), these spears provide the earliest reliable evidence of hunting weapons. Prior to this discovery, evidence for hunting weapons within a similar

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chronological range (ca 400–250 kya) was represented by a lance tip found at the English site of Clacton on Sea (Oakley, Andrews, Keeley, and Clark, 1977), a poorly preserved wooden stick at the site of Bad Cannstatt, Stuttgart, Germany (Thieme, 2005) and some fragments of wooden objects at Bilzingsleben, Germany (Mania and Mania, 2005). Wooden items normally decay, and therefore their conservation happens only when subject to very specific conditions. These rare events of preservation provide invaluable insights into the behavioral and social complexity of these archaic populations, which might actually be underestimated from the analysis of the stone tool record.

The Schöningen site is an open mine and the spears were found about ten meters below the present ground surface. The location is thought to be a lake shore and it was characterized by a swampy environment, rich in vegetation. The spears were embedded in a muck composed by wet sediments, possibly of a delta plain (Lang et al., 2012), with decay impeded by lack of oxygen in the soil.

The spears were discovered in the context of a camp, in association with a set of artifacts and traces of activities suggestive of a complex social organization at this location (Thieme, 2005). The makers of the spears are generally ascribed to the *Homo heidelbergensis* taxon (Coolidge and Wynn, 2009, p. 151), given the overlap between the chronological distribution of this species and the dating of the artifacts (Street, Terberger, and Orschiedt, 2006). Although sharing a robust facial anatomy with the more primitive *Homo erectus* taxon, *Homo heidelbergensis* shows derived features that are typical of later hominids. Focusing on cranial anatomy, these features include frontal and occipital proportions, parietal convexity, arching of the temporal squama, orientation of the nasal aperture, anatomy of the underside of the skull, and an average brain capacity of ca 1200 cc (Rightmire, 2007). A set of flint-made stone artifacts has been found in the Schöningen site, including retouched scrapers and some points, which were produced elsewhere and then transported to this location where the hominids reworked them. There was evidence of four hearths (but see Stahlschmidt et al. [in press], for a counterargument), which are all located in the Western part of the camp, suggesting a spatial organization of activities within a social space.

Evidence of butchering large mammals was present in several earlier sites, but an association with weapons would be needed to prove the effective involvement of hunting strategies. In fact, these earlier butchered remains may have resulted from scavenging activities or opportunistic hunting (e.g., animals naturally entrapped or injured). However, the Schöningen spears were found in association with the remains of twenty horses, which were killed and butchered in loco. Furthermore, the spears appeared to resemble modern javelins with a centre of gravity designed for throwing (Tattersall, 2006, p. 174). Thieme (2005) initially explained this body of evidence as a result of a single event involving the interception of a whole herd of horses. The hominids at Schöningen would have ambushed the herd with throwing spears and butchered all the animals. However, new data suggest that the horses were associated with different hunting/butchering events (Rivals et al., in press) and that the bones accumulated in the same location over time. Although weakening the idea that local populations had evolved coordinated strategies for mass killing, this evidence is sufficient to prove that *Homo heidelbergensis* populations were consistently relying on big-game hunting. In sum, the evidence from Schöningen was suggestive of cultural and technological sophistication in these pre-modern human populations, thus overturning the orthodoxy that these hominids were limited to basic subsistence strategies, simple social organization, and a relatively static material culture, mostly represented by the realization of bifacial stone-tools (Ambrose, 2001; see Lycett and Gowlett, 2008 for a review).

Before the discovery of the spears, the cognitive archaeology of the Lower Palaeolithic material culture broadly focused on two aspects. Some scholars attempted to draw inferences from the features of the stone tools to the properties of language (e.g., Holloway, 1969). Such an approach, however, was criticized because the cognitive properties required to produce stone tools do not necessarily entail the presence of similar abilities in the language domain. For example, the control of sequential operations required in stone-tool knapping does not warrant the existence of an analogous mechanism in the control of sequential morphemes during speech (see Barnard, 2010a for a related analysis).

Other scholars adopted a safer epistemology, focusing on spatial cognition, as evidenced by the emergence of progressively more symmetric stone tools in the record (e.g., Wynn, 1989). In the case of *Homo heidelbergensis*, increased symmetry differentiated the roughly shaped bifacials of the early Acheulean period from the more coherent ones of the late Acheulean. Such evidence resulted in alternative explanations about the minimal cognitive requirements necessary to produce symmetric artifacts (see Wynn, 2002 and the related commentary). However, Wynn concluded that symmetric stone tools support the existence of potential cognitive enhancements that apply only to an isolated aspect of the mind, specifically, spatial cognition. In consequence, *Homo heidelbergensis* was still to be considered as cognitively archaic in many respects, since a wider analysis of their material culture did not support equivalence with modern humans.

Nevertheless, the Schöningen artifacts led some scholars to reconsider this initial conservative explanation. These artifacts were interpreted as evidence that *Homo heidelbergensis* was capable of in-depth action planning (Dennell, 1997) and foresight (Thieme, 1997). Such considerations led to the argument that the spear-makers had mastered sophisticated operational chains of actions, which required some degree of abstract reasoning, complemented by verbal communication (Mania and Mania, 2005; Thieme, 2005, p. 129). The combination of abstract reasoning, complex planning and language led scholars to conclude that *Homo heidelbergensis* had some intellectual capabilities that were previously considered as typical only of modern humans.[1] These cognitive properties represented advancements that

[1]This statement will be henceforth referred to as "the initial assumption."

extended far beyond the visuo-spatial domain, as hypothesized by Wynn (2002). In the cognitive archaeology debate, some scholars (d'Errico and Stringer, 2011; Zilhao, 2011) have recently embraced an extreme form of this argument, by contending that the bases of "modern cognition" have been present in human populations from 500 kya. However, the reasons why abstract concepts and language ought to be considered as necessary to produce these new technologies were not specified, and the core arguments are based on a set of a priori assumptions.

Aims of the Paper

I will argue that the production of the Schöningen spears required no qualitative enhancement of pre-existing cognitive capabilities such as the emergence of abstract cognition, in-depth planning, or linguistic meta-representations. In contrast, I aim to show that a set of embodied and situated strategies, grounded in perception, is sufficient to explain the spear-making process. Firstly, I shall adopt a conservative embodied cognitive approach, based upon the use of re-enacted simulations/perceptual concepts (e.g., Barsalou, 1999; Prinz, 2002), to question the presupposition that any form of abstraction involved in the spear-making process necessarily requires a qualitative leap towards a modern cognitive architecture. I shall then consider in-depth action planning/foresight by focusing on the notion of internally mentalized plans as opposed to an enactive conception of action organization. A radical embodied cognitive approach will be adopted to show that no mental representations must be a priori applied to the spear-making process. It will be argued that this body of situated abilities is also shared by Acheulean tool-making and therefore lies within the capabilities of more primitive human populations. The current analysis will thus seek to demonstrate that the cognitive capabilities postulated by the initial assumption (Thieme, 2005) are either non-necessary or non-modern. At least for the manufacture and cultural transmission of these spears, the most parsimonious conclusion is a requirement only for a quantitative advancement in mental capabilities over earlier hominids.

A Closer Look at the Schöningen Spears

The two-meter long Schöningen spears were produced using stone tools to work selected material from small spruce or pine trees. Haidle (2009, p. 68) argued that the process of manufacture involved an extended chain:

> in the use of a tool (e.g., hammerstone) to produce a tool (knap a stone tool) to produce a tool (carve the wooden spear) to manipulate an object (hunt an animal) to satisfy a basic need (hunger).

This exposes the distance (Haidle, 2012) between a problem (satisfaction of hunger) and its solution (the sequence of behavioral operations that leads to succeed in the hunting task). Haidle further analyzed the problem-solution distance with reference to the experimental evidence proposed by Veil (1991) as a plausible model accounting for the processes required in making a spear. The method of coding perception and action sequences in cognigrams (Haidle, 2009), namely, analytical extensions of the *chaînes opératoires* approach (e.g., Pélégrin, Karlin, and Bodu, 1988; Schlanger, 1994), was applied to the problem-solution distance. Specific operations were nested in the whole sequence as a series of sub-routines (see Haidle, 2010, 2012; Lombard and Haidle, 2012 for additional examples). Each of the elements nested in the sequence could be considered as a relative problem that requires a specific solution in order to advance to the subsequent step in the longer problem chain (i.e., making a spear to kill the prey). Table 1 shows the basic set of operations required for the spear-making process at Schöningen, according to Haidle (2009).

Table 1

Basic Chain of Subproblems Implied in Hunting a Prey with a Spear (Haidle, 2009)

Problem type	Problem definition
Basic need	hunger
Subproblem 1	hunt prey
Subproblem 2	need of spear (tool 1)
Subproblem 3A	need of handaxe to cut down tree (tool 2): quality A
Subproblem 3B	need of handaxe to cut down tree (tool 2): quality B
Subproblem 4	need of flake tool (tool 3) to work wood
Subproblem 5	need of hard hammerstone (tool 4) to produce tool 3 and work on tool 2
Subproblem 6	need of a soft hammerstone (tool 5) for retouch of tool 2

The sequence begins with the basic need of satisfying hunger, the origin for the problem of hunting prey (subproblem 1) using a spear (subproblem 2). The following subproblems show the operations required to chop off part of a tree (subproblem 3A–B) and to work it (subproblem 4). The operations are carried out using different kinds of stone tools, which in turn require other stone tools for their manufacture (subproblems 5–6).

An intricate network of raw material procurement, tool production, and item transportation could have been carried out over several days. According to Haidle (ibidem, p. 72), it seems quite implausible that a pre-modern species like *Homo heidelbergensis* would have approached spear-making by keeping in mind all the intermediate goals of the whole plan, repeatedly calling to mind this cognitively demanding plan every time they needed to hunt for food. More likely, stone tools could have been made for other tasks as well, rather than specifically brought into being for spear manufacture. In this way, they could have been produced and used as modular units, providing hominids with independent solutions applicable to a range of potential problems (Haidle and Conard, 2011).

Haidle's analysis is relevant for revealing the operational sequences that underlie behavioral practices reconstructed from the archaeological record. However, mapping properties of behavior to properties of cognitive systems requires a different form of explanation that needs to be separately specified in cognitive archaeology. This aspect becomes particularly important when considering the idea that Haidle's operational chain offers a "neutral" description of the spear-making process, a description that is not situated in any specific historical context and that is applicable to all contexts. Cognitive explanations are in fact sensitive to the historical development of a technology. The operational chain might indeed refer to a long-term instantiated spear-making practice, which is performed by means of expert cognitive strategies. In contrast, a very different body of cognitive explanations might emerge if we consider the same operational chain as underpinning the invention of a new technology. I will focus specifically on reconstructing the cognitive requirements for this latter situation of invention.

The Many Faces of "Abstraction"

Key questions need to be addressed before we can draw any conclusions concerning a putative involvement of complex abstract thinking in these archaic populations' invention and use of spears. What do we mean by abstraction? And why and how might a given form of abstraction be involved?

Lawrence Barsalou (2003a, 2005) suggested that the concept of abstraction can be interpreted according to six different senses:

Sense 1. Abstraction as categorical knowledge: the cognitive ability to create general conceptual categories from classes of instances that are met in experience.

Sense 2. Abstraction as the behavioral ability to generalize across instances: the behavioral ability to produce abstractions of the first kind. Namely, the fact that people can summarize the properties of one or more category members behaviorally.

Sense 3. Abstraction as summary representation: the idea, according to some theories, that behavioral abstractions are performed at the cognitive level by reading out an underlying summary representation, which can assume multiple forms (e.g., a declarative rule or a statistical prototype).

Sense 4. Abstraction as schematic representation: the idea that summary representations are in fact schematic, for they can abstract critical properties while discarding irrelevant ones.

Sense 5. Abstraction as flexible representation: the fact that summary representations can be applied flexibly to a wide variety of tasks, such as categorization, inference, language comprehension, reasoning, etc. According to this sense, increasing abstractness raises the flexibility of a representation.

Sense 6. Abstraction as abstract concepts: abstraction can refer to the degree of concreteness that characterizes a concept. When concepts become detached from physical entities and associated with mental events, they are considered to be abstract.

The six senses show that abstraction is an ambiguous concept unless defined clearly. Hence, the drawing of inferences about cognitive modernity is unwarranted unless we are clear about what we mean by the term. For example, abstraction as categorization (sense 1) does not necessarily lead to the production of abstract concepts (sense 6). The concept of DOG, according to a classic paradigm (Machery, 2009, sec. 4.2), could be a prototype derived from superimposing entities whose properties show sufficient statistical similarity. This operation could simply lead to the formation of a concrete concept. In contrast, the concepts of RESPECT, DEMOCRACY, or JUSTICE are clearly abstract in the sixth of Barsalou's senses. These two senses are not necessarily associated. It is possible that primitive mental systems can work with concrete abstractions, but no more than that. At the same time, it is also possible that some variants of abstraction are uniquely confined to a modern human mental architecture. I assume that three of the six senses of abstraction are relevant to the current analysis about the minimal cognitive requirements to produce the Schöningen spears, namely 1, 5 and 6. While these senses describe abstraction in terms of a series of cognitive abilities, senses 3–4 concern instead more foundational aspects about the nature of mental representations and their role in the process of abstraction. In this way, these senses are orthogonal to the discussion. In the next section I will attempt to demonstrate that those definitions of abstraction that prima facie seem to require a modern cognitive architecture are not necessarily involved in the spear-making process. In contrast, I will show that the senses of abstraction that most likely apply to the Schöningen spears are not uniquely modern.

Why Abstract? How Abstract?

Traditional theories in cognitive science argue that conceptual knowledge inhabits a modular semantic system, which stands as separate from modality-specific systems for perception, action and emotion, as well as from episodic memory (e.g., Fodor, 1975; Pylyshyn, 1984; Tulving, 1972). Concepts are represented by transducing modal states into amodal representations, which could take the form of a list of features or a semantic network. Amodal concepts thus instantiate the fundamental units that are manipulated during cognitive operations.

In contrast, an important body of theory (Barsalou, 1999, 2012; Barsalou, Solomon, and Wu, 1999; Prinz, 2002) asserts that human concepts are to be considered as perceptual symbols, namely, representations that are grounded in specific sensorimotor codes. Perceptual symbol systems are based on a natively constrained neural architecture, which combines modality-specific neurons with associative areas of the brain. Firstly, different features of perceptual experience activate different neural detectors within modality-specific systems. Considering the case of vision, for example, neural feature detectors situated in the visual system respond to particular features of the percept. Secondly, conjunctive neurons in associative areas (Damasio, 1989; Damasio and Damasio, 1994) enable the conjoint of perceptual information about objects/events derived from the various neural feature detectors. These conjunctive neurons increasingly integrate information across modalities, thus producing multi-modal rather than amodal representations. Categorization and use of concepts in cognitive processes is conceived as a form of simulation of that category, which follows from an actual process of neurophysiological re-enactment (Barsalou, Simmons, Barbey, and Wilson, 2003). In this way, conjunctive neurons can partially re-activate neural detectors that were originally responding to perceptual features of the environment. This process of simulation/re-enactment can be consciously performed, like in the case of visual imagery (Collins, 2013, chapter 4) and imagistic reasoning (Kosslyn, 1994). In these cases, simulations consist of partly re-constructing the phenomenology of an object/event in the absence of sensory input. On the other hand, simulations could also be unconscious, as it happens for instance in preconscious processing and automated skills (Barsalou, 1999, p. 583).

The idea that situated concepts play a major role in human conceptualization has been subject to several critiques, which in turn generated responses (see Barsalou, 1999 and the associated commentary). Most importantly, it has been argued that situated concepts are best suited to explain only highly imageable, concrete concepts. Their role in the representation of abstract concepts (e.g., DEMOCRACY) is more contentious. Dove (2009), after examining arguments for and against perceptual concepts, has concluded that the most plausible explanation assumes representational pluralism. From this perspective, perceptual symbols can coexist with amodal representations, so that abstract concepts can be represented by the classic amodal theories (definitions, prototypes, exemplars, theories), while concrete, highly-imageable entities can be represented in the form of perceptual tokens. A different proposal advances linguistic forms instead of amodal concepts as the means to represent abstract concepts (Barsalou, Santos, Simmons, and Wilson, 2008). The latter are to be considered as networks of labels, which are semantically connected to perceptual representations by convention and cultural scaffolding. This theory advocates a combination of language and sensorimotor simulations (LASS). If representational pluralism or LASS are true, then we can assume that modern humans rely on different representational substrates that allow them to flexibly engage with everyday tasks. Most importantly, if abstract concepts require amodal structures or language in order to be produced, any involvement of this sense of abstraction in producing artifacts might reasonably constrain the presence of a modern cognitive architecture, as supposed by the initial assumption (Thieme, 2005).[2]

The crucial aspect for the present discussion about the Schöningen spears is that representational pluralism or LASS do not need to apply with *Homo heidelbergensis* spear-makers. Indeed, no form of abstract conceptualization (sense 6) seems to be present in the spear-making process to require either amodal structures or linguistic scaffolding. On the contrary, the whole set of behavioral operations in Table 1 seems to be more parsimoniously explained by referring to perceptual simulations and image-based thinking.

How to Simulate a Simple Spear

A set of thought experiments can best illustrate the key aspects of my argument. The overall logic involves imagining the invention of a spear by means of abstract concepts and then contrasting this approach with a conservative embodied perspective based on perceptual simulations of concrete object/events. Let us consider how a hominid, armed with tools, approaches the problem of satisfying hunger by hunting a horse. I assume, as Haidle did, that *Homo heidelbergensis* could have relied on stone tools as modular units that can be used in a range of tasks. According to Table 1, hunting a prey entails "need a spear" as a sub-problem. However, if we consider the spear-making process as a practice to be invented and established, then the concept of spear must first itself be conceived. In this way, the hominid explores his habitat with pre-existing mental and physical resources, searching for a solution to the problem. The spear-making process begins when the hominid notices a pine or spruce shaft. At this point, abstract concepts could be used to support and justify each potential cognitive operation that aims to explain the underlying behavioral sequence. We might assume, for instance, that the hominid compares the perceived shaft to the abstract concept of POINT or to the composite one of POINTED OBJECT. The hominid "knows" that a POINT is necessary to kill the animal by THRUSTING and therefore deduces that a shaft has the right properties to be made into a stabbing tool. Further sub-problems related to using stone tools for cutting the trunk and carving out the spear could clearly be tackled with the same reference to abstract conceptualization and reasoning.

[2]The involvement of linguistically scaffolded abstract concepts plausibly constrains the existence of a modern cognitive architecture in Barnard's (2010b) conception. In contrast, amodal concepts lack implementation in this theory of cognitive architecture and therefore their connection to modern cognition is assumed as a logical possibility, which might be thought to motivate the initial assumption on the Schöningen spears. The possibility that humans could have evolved an entirely different representational system is discussed by Barsalou (1999, p. 606). Whether this hypothesis is sound or not, the current analysis flanks the problem by rejecting any necessary involvement of amodal or linguistically scaffolded abstract concepts in spear-making.

However, despite this logical possibility, I contend that no form of abstract concept is necessary to explain the spear-making process. Each of the behavioral components of the chain under consideration is highly imageable/concrete and therefore within the scope of the situated approach introduced earlier. For example, in the context of a tree shaft, it is not necessary to postulate the existence of a concept of POINTED OBJECT in order to produce a spear. These hominids would have been repeatedly interacting with a wide range of naturally occurring forms or those modified by conspecifics. Such interactions could have led these pre-modern humans to be well acquainted with specific recurring properties, such as for example the fact that some of the objects were indeed pointed and that sharp tips can pierce the skin. Furthermore, explorative actions with stone tools might have revealed that scraping some particular branches and pieces of wood in a specific way produces sharp points. In this way, the concept of SHARP POINTED STICK could emerge through the practical engagement with these objects and be represented as a form of situated action.

Once such situated concepts are in place, an appropriate wooden shaft found in the environment could lead the hominid to re-enact perceptual simulations of known pointed objects. These re-enacted simulations could allow the hominid to imagine a weapon inside the shaft as well as the operations needed to carve the weapon out from the shaft. The same logic also applies to the rest of the sub-problems shown in Table 1. In particular, referring to subproblem 3A, "need of handaxe to cut down tree," sensorimotor simulations could readily reveal the properties of suited stone tools and support the selection of appropriate actions. The same would hold for subproblem 4, "need of flake tool to work wood." Furthermore, action control could be carried out by contrasting the simulated weapon with the specific properties of the actual tree in view at the time. In sum, by grounding in perception the operations underlying the invention of a spear it is no longer necessary to refer to abstractions in Barsalou's sense 6.

Objections and Replies

Skeptics might argue that this position does not rule out abstraction in sense 1 or 5. Sense 1 in Barsalou's list, namely categorization, might be used to argue that the perceptual representations underlying the spear-making process are nevertheless "abstracted" from experience. However, it is unclear how this point could be used to argue that sense 1 of abstraction constrains the existence of uniquely modern cognitive capabilities. To defend a similar position requires the assumption that conceptualization and the cognitive use of knowledge emerge with *Homo heidelbergensis* and represent the original roots of a modern-like cognition. While empirical evidence indicates that monkeys and apes are capable of acquiring concepts (e.g., Vonk, Jett, Mosteller, and Galvan, 2013), our skeptic faces also theoretical problems. Both Mithen (1998) and Haidle (2009), for example, compared spear-making to the behavior of chimpanzees out hunting bushbabies (Pruetz and Bertolani, 2007). If the ability to create simulators itself is the subject of criticism, then it is unclear how a chimpanzee could keep a problem in its working memory (i.e., hunting the bushbaby) while attempting to solve a subproblem routine (i.e., finding an appropriate branch to stab the prey into its nest). The problem is compounded when applied to early forms of tool-making. Absence of abstraction in sense 1 therefore leaves open the issue of how to explain offline representations held in memory. More widely, it posits the problem of justifying the use of conceptual knowledge in non-human animals (Barsalou, 1999, pp. 606–607).

Even if the point about categorization were to be conceded, one might argue that the Schöningen spears still represent a leap towards modern human abstraction in Barsalou's sense 5, namely flexibility. According to this criticism, the spear-making process would somehow demonstrate that simulations can be performed beyond the isolated context of spear manufacturing and used in a rich gamut of cognitive activities. In contrast, more archaic hominids, as well as non-human animals, could have relied only on context-bound forms of situated conceptualization. In these archaic mental systems, perceptual simulations would be strictly bound to particular situations and therefore capable of representing only specific instances of events/objects.

The most problematic aspect of this explanation is that the spear-making process could also be based on context-bound conceptualization. Even though a certain degree of flexibility might be present in using the concept of SHARP POINTED STICK in the same material domain, this does not entail that such a simulator could be flexibly adopted in a different range of situations, transformed into an ad hoc category (Barsalou, 2003b), or could be applied to producing new weapons and technologies. For example, *Homo heidelbergensis*' cognitive system could have lacked the flexibility to turn a spear into a bow and arrow technology (Lombard and Haidle, 2012) or into a pole to support a stilt house. An analysis of these hominids' material culture, given the culture's relative stability in time, prima facie does not support a strong case for this type of cognitive flexibility (Wynn, 2002).

Raising the Ante: Throwing Spears

The arguments so far might hold for spears as thrusting weapons, whose use involves physical contact with the prey. The spears from Schöningen appear to be balanced for throwing, much like modern javelins (Thieme, 2005, p. 125). Several researchers have questioned whether the spears were actually thrown, and have provided different arguments (d'Errico and Stringer, 2011, pp. 1063–1064), including whether the anatomy of the upper limbs was sufficiently developed for throwing (Churchill and Rhodes, 2009); whether such spears could actually bring down big game if thrown from a distance (R.G. Klein, 2009, p. 404; Wynn and Coolidge, 2012, p. 50); and whether the spears were possibly too heavy or large for throwing (Shea, 2006; but see Rieder, 2003 for a counterargument). However, if the spears were thrown, there is a further challenge for any situated cognitive approach. For example, Zilhao (2011, p. 118) assumes that in order to produce and use long-range hunting weapons, their makers must have "mastered the laws of ballistics before Neanderthals." Against this background, it is worth examining whether the use of spears as projectiles would reintroduce the need for abstract concepts in the process of manufacture.

Coolidge and Wynn (2009, p. 167) have argued that *Homo heidelbergensis* must have been capable of understanding properties of Euclidean space in order to organize their actions. However, this was limited to some form of intuitive understanding without a formal grasp of, for example, spatial coordinates. An expert cognition, repetition-based approach (Wynn and Coolidge, 2004) is quite sufficient without requiring reference to Euclidean space.

The innovation of throwing weapons could plausibly have developed out of prior use of stabbing weapons in a hunting context. Thrusting weapons could have been let go in the course of a thrust, in order to minimize the risk of injury in big game hunting. On the other hand, this practice could have also capitalized on pre-existing habits of throwing manuports, for example, to keep predators like hyenas at bay. From these practices, *Homo heidelbergensis* populations could have gradually discovered the proper features a weapon ought to have to act as a projectile. Then, they could have learned to produce spears with "throwing" properties, by learning how to control specific technical processes (e.g., tree choice, carving procedure). At the cognitive level, this learning could well have been accomplished by comparing perceptual instances of some spears with situated simulations of the technical procedures required to produce them. No abstract representational form, like INCLINATION, ATTRITION, CENTER OF WEIGHT, needs to be a priori cognized in order to produce a correct balancing of the spear. If these components are excluded, however, the principles of ballistics mentioned by Zilhao (2011) can be considered as simple practical laws that are acquired by combining action dynamics with situated representations.

A Radical Reinterpretation

The conservative embodied view presented earlier can still be subject to a mentalistic conception. This considers the behavioral sequence of operations reported by Haidle (2009) as reflecting the presence of a cognitive plan, which addresses each sub-goal and sub-routine in terms of input–output. In this way, skeptics might concede that abstract cognition is not necessary for manufacturing spears. However, they could still claim that realizing a spear involves modern "in depth-planning," which takes the form of a series of inferences advanced from a set of mental representations, though grounded in perception. In-depth planning would prove a qualitative overlap in cognitive functions between *Homo* *heidelbergensis* and modern humans, as postulated by the initial assumption (Thieme, 2005). The aim of the current and the following section will be to provide a radical embodied counterargument to this objection. This alternative view will be developed by combining ecological principles of perception and intuitive interaction theory.

According to James Gibson's (1979) ecological approach, perception does not require the a priori use of concepts in order to make sense of the world. In visual perception, our brain does not process the stimulus registered on the retina by adding information concerning native or acquired categories. Rather, information is already present in the structure of the environment itself. Most crucially, perception is radically embodied, in that meaning of the world emerges directly in the interaction between agents and their environment. Since agents have certain body features, elements of the world are directly perceived as a set of affordances for action (e.g., Chemero, 2003, 2009, chapter 7). For example, a surface does not appear as climbable for the fact that it is inferentially judged as flat. Rather, when the agent navigates the environment, the surface presents some invariant properties that allow the agent to directly perceive it as climbable.

Intuitive interaction is a research program developed in the context of product design with the aim of simplifying human–artifact interactions and minimizing users' cognitive load (Blackler, 2008; Blackler, Popovic, and Mahar, 2010). Intuition is defined as a direct/non-inferential process of knowledge acquisition based on past experience (e.g, Bastick, 2003; G. Klein, 1998; Volz and von Cramon, 2006). Empirical studies in this field have shown that the key for reducing complexity lies in exploiting users' previous experience with similar artifact interfaces or real life situations (Brandenburg and Sachse, 2012; Pearson and van Schaik, 2003; Rettig, 1991; Thomas and van Leeuwen, 1999). For example, consistency with the operations usually performed in a real office environment has represented a guiding principle to develop human–computer interfaces during the last decades (e.g., see Smith, Irby, Kimball, and Verplank, 1982, about the revolutionary Xerox Star Interface, which first implemented the "you get what you see" principles). Familiar actions like moving a book from a shelf to a desk have been exploited to design interfaces that simulate the transferring of a folder onto a virtual desktop. Users understand the artifacts' rules of functioning by actively engaging with them in their living contexts. Intuitive understanding happens when features of new artifacts trigger analogous features and rules of functioning of familiar artifacts from long-term memory (Bowers, Regehr, Balthazard, and Parker, 1990; Kolodner, 1993; Richman, Gobet, Staszewski, and Simon, 1996, p. 180). Such an intuitive connection is fast, efficient, and mostly unconscious (Bowers, 1984; Dijksterhuis and Nordgren, 2006), for the user has the feeling of knowing how the artifact works without a clear awareness of how he reached such an understanding (Horr, Braun, and Volz, 2014).

The importance of intuition in designing human–artifact interfaces is represented by the fact that this cognitive process reduces the involvement of knowledge-based approaches to understanding artifacts (Rasmussen, 1990). If users can exploit their past experience in a fast, efficient, and quasi-automatic fashion, then they would need to employ theoretical knowledge about how artifacts work (Naumann et al., 2007). Increasing the intuitive aspects of human–artifact interfaces therefore leads to a better usability of the products.

Interestingly, intuitive interaction theory is positively oriented towards embodied cognition and ecological psychology (Blackler, 2008, pp. 21–23, 89–94). Past experience in user–artifact interaction is indeed conceived as the learning of affordances that are "virtually" built within the cultural context where agents and artifacts are situated (Norman, 1988). In the current paper, intuition will be used as a cognitive process to bridge ecological and enactive principles of perception, action, and memory, with the aim of ruling out mental plans from the spear-making process.

Intuitive Resonance

Homo heidelbergensis spear-makers developed in a cultural milieu that allowed them to interact with stone artifacts as problem-solving tools. Likewise, evidence of wooden objects from Lower Paleolithic sites besides Schöningen (see the Introduction), though quite limited, supports the idea that these hominids were also familiar with the properties of wood and plausibly with the interaction between wooden objects and stone tools. As a result of such a long-term material engagement (Malafouris, 2004, 2013), these artifacts become deeply embodied in the hominids' perceptual systems, capable of perceiving new affordances for action in the world. The perceptual system thus becomes extended by memory (Gibson, 1979, p. 279), since affordances for action are memorized as variations of sensorimotor features of objects in relation to embodied activity (Noë, 2004, p. 105; O'Regan and Noë, 2001).

Simply looking at a tree can trigger affordances for action that have been acquired from potentially extensive past experience of, for example, other similar shaped branches and how they are joined to a trunk. Past experience of multimodal sensorimotor contingencies may also resonate with particular perceived features of the tree by means of a deep intuitive sense of similarity and association. Intuition leads therefore to an automatic understanding of the affordances of the constituent parts of a tree. In this way, hominids could directly perceive the possibility of carving a spear out of a tree branch and trunk. This "spear-derivability" affordance is apparent when other affordances like "ability-to-be-chopped-off" and "bark-reduction" are also perceived. As the sequence of actions involved in manufacturing a spear gradually unfold, so the "hunting an animal affordance" would become increasingly evident to the maker or to others in their band who might be observing that process.

Furthermore, subproblem 1, namely hunting an animal, is kept coupled to the agent–artifact system by the progressive chain of actions leading to the emergence of a thrusting weapon. The refinement of the pointed tip affords killing by thrusting, which in turn complements being killed by thrusting. In sum, every aspect of the process is coupled within the dynamics of action and perception underlying the spear-making process.

Unlike the conservative embodied model discussed above, the radical reinterpretation does not involve that mental representations are compared with percepts in order to draw inferences and accordingly organize actions. The spear-making artisans did not need keep in mind subproblem 1 "hunt prey" and subproblem 2 "need of spear" as a sort of conceptual premise according to which he organized action. With respect to any putative involvement of conceptual knowledge, there is a direct parallel with the discussion provided earlier about the non-necessity of abstract concepts and the sufficiency of sensorimotor simulations of concrete objects/events. However, in the current radical embodied version, concepts and memories *resonate* with affordances by means of intuition and are not used a priori to discover meaning of an aspect of reality. Conceptual representations can in fact be enacted from memory while perceiving affordances, letting the plan emerge and take form while perceiving relevant aspects of the world.

Intersubjective Spear-making

It could be pointed out that the spear technology was not systematically reinvented by *Homo heidelbergensis* every time they needed it, but transmitted from experts to novices across generations. At the same time, there are reasons to believe that such a transmission was grounded in active teaching–learning mechanisms. Indeed, the complexity of the tasks involved in the production of Acheulean artifacts, such as symmetrically coherent handaxes (Wynn, 2002), dissuades one from thinking that the spear-makers relied on learning strategies based on imitation/emulation (Morgan et al., in press). If these were the only existing mechanisms, coherent handaxes, for example, should appear only very rarely in the record, surrounded by a great amount of failed imitative attempts and incomplete tools. This would make difficult to explain cases such as the high standardization of bifacial forms appearing in African sites from ca 700 kya (Pélégrin, 2009; Roche, 2005), unless one implausibly assumes that these artifacts were produced only by few gifted individuals.

The active transmission of the spear-making process could have happened through the construction of an internal model of a spear. Expert spear-makers could have shared this mental template with novices by adopting language-based meta-representations, which allow one to represent the mental states of the other individuals "as such" (i.e., I know what you believe, wish, or think). In this way, social transmission of expertise could be argued to reintroduce the costly cognitive strategies eliminated from the individual dimension within the previous discussion.

However, according to a radical embodied argument (Hutto and Sánchez–García, in press), such a mentalistic approach does not represent the actual way learners acquire practical expertise from their teachers. Evidence from the musical domain allows us to understand the main aspects of the radical embodied principles of skill transmission and acquisition. Laroche and Kaddouch (2014) have recently discussed the case of enactive learning of piano playing abilities through four-hand improvisation. In this situation, a teacher sits at the left part of the piano, which represents low notes, while a young learner sits at the right side, corresponding to high notes. Four-hand improvisation is not based on representing and sharing an internal melody, made of theoretical relations among the notes. On the contrary, the two players create an intersubjective system, where the activity of the one influences and shapes the activity of the other (De Jaegher, 2009; Fuchs and De Jaegher, 2009). Mutual understanding emerges from interactive modulations of individual actions, a process also known as "participatory sense-making" (De Jaegher and Di Paolo, 2007). The novice begins to play notes by relying on her prior experience. The teacher enters in resonance with these basic patterns and gradually alters his playing in order to drive the learner towards a new pattern. In this way, the melody played by the teacher provides the affordances for action that the novice learns to exploit with experience. At the same time, the teacher can perceive when the novice hesitates in adapting to the new patterns and regulates his actions to help facilitate the learning process.

The principles of participatory sense-making introduced above apply also to the transmission of the spear technology. Let us consider the case of a single hominid that invents a spear by means of intuitive resonance with a tree shaft (see above). The other band members can exploit this situation by adopting a hybrid learning strategy articulated in two steps (Sterelny, 2011, chapter 2). First, they can indirectly analyze wooden flakes and debris left back by the expert's crafting activity. Such an explorative ability allows them to become familiar with some preliminary aspects of the technique and to acquire a basis of individual experience. Second, and most importantly, they can directly refer to the expert as a model for knowledge acquisition. In this way, the expert and the apprentice form an intersubjective system, similar to the one described for piano improvisation.

The spear-making technique is acquired by the novice as a result of a mutual engagement with an expert practitioner. The actions adopted by the expert to craft a spear with handaxes directly represent what is needed to be done. The novice attempts to reproduce these patterns with his own tools by directly comparing his performance with that of the expert. This, in turn, modulates the activity of the novice, leading him to discover how to solve problems with the carving process. Intentionality is directly perceived by both agents as an embodied action directed toward the tool–agent complex (see Garofoli, in press, for a similar account). No mentalistic abilities are necessary to realize this intersubjective system. In particular, language need not be used to represent and share an ideal model. A large part of this system can be realized in a non-linguistic way, while vocalizations can be initially used as epistemic tools to support the meaning of embodied actions (Stout, 2002, p. 719). For example, vocal emphasis can be used by the expert to mark the correct copying of a technique by the apprentice, or to draw his attention on a mistake. This seems to be the case also in some contemporary ethnographic contexts of apprenticeship like blacksmithing (Keller and Keller, 1996; Wynn and Coolidge, 2004). Primitive vocalizations can gradually become indexical of particular actions or events (Brown, Collins, and Duguid, 1989) and scaffold the emergence of abilities like abstract concepts or meta-representations in the long term. Situated apprenticeship thus represents a necessary condition for the emergence of abstractions and not the other way around.

Drawing from Sperber (2000), Sterelny (2011, chapter 6) argues that humans did evolve specific meta-representational abilities that allowed teachers and learners to coordinate actions according to a "mentally shared" plan. However, these mentalistic strategies may be relevant for apprenticeship only in quite recent cultural contexts (Wynn and Coolidge, 2012, p. 70). By embracing an argument from phenomenology (de Bruin and de Haan, 2012), enactivists claim that social understanding grounded in mentalistic abilities like theory of mind is in fact not primary even in contemporary societies, where perception of social affordances, augmented by contextual knowledge and narratives, plays the main role (Gallagher, 2008; Gallagher and Hutto, 2008; Garofoli, in press). Furthermore, the emerging radical embodied approach to Dreyfusian pedagogy (Dreyfus, 2012; Hutto and Sánchez–García, in press) argues for abandoning shared abstractions when developing training strategies for novices. Evidence from sport science shows indeed that the adoption of shared abstractions impairs task acquisition and performance (Beilock, 2008; Davids, Araújo, Hristovski, Passos, and Chow, 2012), since the use of explicit cognitive strategies interferes with the embodied realization of a task, a phenomenon known as "choking" (Beilock, 2011). In sum, the multiple sources of argument introduced above show there is a paradox in assuming that mentalistic strategies, considered secondary in modern contexts, were necessary to the transmission of Lower Paleolithic spears.

Discussion

The results of the current analysis show that intuitive resonance is sufficient to explain the spear-making process at Schöningen. This radical embodied cognitive process eliminates the involvement of presumed modern human-like abilities, namely abstract thinking and in-depth action planning. Further, intuitive resonance is considered to be similarly involved in producing both Acheulean tools and the Schöningen spears. Indeed, direct perception of affordances for action, augmented by previous experience, can explain the production of these artifacts. Besides this similarity in the general cognitive requirements, affinity between these two technologies also exists at a more specific level. Indeed, some affordances for action seem to be invariant between the two considered practices. For example, stone reduction and bark reduction could be grounded on the perception of analogous affordances for "reducing a core."

This conception is consistent with some of the more skeptical views about the Schöningen spears. R.G. Klein (2009), for example, argues that the cognitive complexity of the spear-making process equals that of stone-tool making, since wooden spears and stone tools still imply the presence of one tool to produce another, a conception also within the idea of modular culture (Haidle and Conard, 2011). In consequence, fabricating stone tools entails the same level of "foresight and control" (R.G. Klein, 2009, p. 407) required to manufacture simple spears. More specifically, the two technologies tap into the same set of cognitive and neural processes, purposed to the control of reiterated operations (Ambrose, 2010). From the radical embodied approach, these proposals have merit in that they emphasize the qualitative stability in the behavioral and cognitive processes underlying spear-making, which can be seen as the emergence of new affordances for artifact-making in both stones and tree trunks. However, the skeptics underestimate the quantitative augmentation that a perceptual system must have to start to detect the affordances necessary to produce spears. In fact, perceiving affordances for cutting in a stone tool and affordances for imposing edges and rough symmetry to the same object might be easier than directly perceiving a spear into a tree. Expertise in Acheulean tool-making can be based upon becoming attuned to the properties of cores and hammers by actively manipulating them (Bingham, Schmidt, and Rosenblum, 1989; Nonaka, Bril, and Rein, 2010; Reed, 1996; Zhu and Bingham, 2008). However, in the case of spear-making, the perceptual system apparently needs a larger amount of information. Indeed, the learning stage for creating a spear implies a set of different stone tools, namely handaxes for chopping off trunks and scrapers for removing bark and working out the wood to be integrated within the perceptual system (Table 1).[3] Such an integration requires acquiring expertise with multiple stone tools and at the same time using these tools to explore the properties of wooden objects. In addition, properties of animals and affordances of objects necessary to hunt them need to be included within the creative process. A system capable of this integration might therefore need higher capacity than that possessed by *Homo erectus:* simply able to pick up cutting affordances and to impose a rough symmetry to stone tools (Wynn, 2002).[4] Such a position is consistent with the view that the same mental architecture, common to both *Homo erectus* and *Homo*

[3]See Nonaka et al. 2010, pp. 164–165 (and references therein) for a review of the necessary learning conditions that lead to the emergence of novel technologies and behaviors.

[4]In this paper the notion of cognitive capacity refers to a specific property of mental architecture, namely to the quantity of information that subsystems can carry and reciprocally exchange (Buschman, Siegel, Roy, and Miller, 2011; Halford, Cowan, and Andrews, 2007).

heidelbergensis, increased the amount of information processed by its component subsystems, without any alteration to the architecture's qualitative structure.

Reasons for preferring the radical embodied explanation to mentalistic proposals are to be found in two different lines of argument. Firstly, an approach based on intuitive resonance allows one to avoid the "representational fallacy" that plagues mentalistic theories (Malafouris, 2013, p. 253). There is indeed logical circularity in assuming that a representation of a spear exists in the mind of the artisan prior to its empirical instantiation. A way out from this paradox lies in assuming that abstract conceptualizations and internal plans emerge as a result of natural selection acting on innately specified neural substrates and cognitive functions. However, this solution leaves room for anthropocentric (Knappett and Malafouris, 2008) and deterministic (Tallis, 2011) problems. In contrast, according to the radical embodied proposal, the concept of SIMPLE SPEAR emerges from material engagement with tree shafts and stone tools. In the long term, this concept scaffolds the production of more sophisticated technologies like hafted weapons (e.g., Mazza et al., 2006).

A second motivation in support of the radical embodied proposal lies at the level of plausibility selection. Indeed, if radical embodied cognitive science is sufficient to explain the spear-making process, then the involvement of abstract concepts, for example, becomes disconnected from the archaeological record and is reduced to the status of a logical possibility. Considering logical possibilities as relevant theories openly violates the strict standard of parsimony required in cognitive archaeology (Wynn and Coolidge, 2009). Garofoli and Haidle (2014) recently argued that logical possibilities could escape from their unconstrained status only by adding ad hoc hypotheses, which dramatically reduce their plausibility as theories. In consequence, keeping abstract concepts and in-depth plans as candidate explanations, despite their unconstrained status, implies that we are assuming them as ad hoc theories. There is no reason to accept this kind of explanation when there are easier, empirically grounded ones. However, Garofoli and Haidle (2014) also added that analyses of single and isolated practices are insufficient to draw inferences about the overall properties of extinct minds. To this end, it is crucial to place the explanations provided for single technologies in the context of a wider repertoire of behavioral practices that represent the cultural capacity of one species (Haidle and Conard, 2011). Referring to *Homo heidelbergensis* at Schöningen, radical embodied cognitive science thus needs to explain also the organizational patterns that lead to ambush hunting, as well as to the production of a bipointed wooden tool interpreted as a spit (Thieme, 2005). Likewise, evidence of human-made shelters associated with this species needs to be carefully examined (Gamble, 1999, chapter 4). If any aspect of *Homo heidelbergensis*' cultural capacity would necessarily require using high-level mentalistic strategies, then it would be possible to expect that these same strategies have been also employed for producing the spears. Such a condition would threaten the plausibility of the radical embodied explanation here provided.

Conclusions

Overall, evidence at the Schöningen site has been interpreted as proof of the involvement of intellectual capabilities previously ascribed to modern humans only. In this paper, I have attempted to demonstrate that the production and cultural transmission of wooden spears does not necessarily imply any qualitative advancement that overlaps with modern human cognition. A radical embodied approach has been specified to show that more primitive abilities could have played a pivotal role in the production of this new technology. I have therefore emphasized a role of Gibsonian smart perception in the production of this technology, which eliminates and replaces the need for abstract conceptualization and mentalistic planning from the cognitive requirements underlying the spear-making process. The radical embodied approach is valid insofar as we consider this practice in isolation. Additional analyses about other behavioral practices associated with *Homo heidelbergensis* are required to further validate the current proposal.

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