

Big brains, small worlds: material culture and the evolution of the mind

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New developments in neuroimaging have demonstrated that the basic capacities underpinning human social skills are shared by our closest extant primate relatives. The challenge for archaeologists is to explain how complex human societies evolved from this shared pattern of face-to-face social interaction. We argue that a key process was the gradual incorporation of material culture into social networks over the course of hominin evolution. Here we use three long-term processes in hominin evolution—encephalization, the global human diaspora and sedentism/agriculture—to illustrate how the cultural transmission of material culture allowed the ‘scaling up’ of face-to-face social interactions to the global societies known today. We conclude that future research by neuroimagers and archaeologists will need to investigate the cognitive mechanisms behind human engagement with material culture as well as other persons.

Keywords: cultural transmission; hominin evolution; social networks; global diaspora; neuroimaging; Palaeolithic archaeology

1. INTRODUCTION

Understandings of the cognitive basis of face-to-face interaction fundamental to both primate and human societies have recently been revolutionized by new neuroimaging techniques. In particular, studies have provided empirical support for a shared theory of mind where the embodied simulation of others’ actions, rather than an abstract representational theory of behaviour, underpins understanding of the actions, sensations and emotions of others (Gallese & Lakoff 2005; Gallese *et al.* 2004). It is this common cognitive basis, with its implications for a deep ancestry, which is proving most provocative for those studying human evolution (Stout *et al.* 2008; Grove & Coward submitted). In this paper we set out to expand these interdisciplinary collaborations by adding an archaeological perspective. This necessarily prioritizes the material aspect of social interaction, highlighting the fact that we currently know very little about the neural capacities for the relationships that humans have with other animate and apparently ‘inanimate’ entities.

Animals and objects have formed a fundamental element in networks of human agency and sociality throughout our *ca* 5 Myr evolution as an encephalized species. For example, the basic skills underpinning interaction with material culture are present in our primate relatives in both the old and new worlds (McGrew 1992; de Amoura & Lee 2004; Davidson & McGrew 2005), suggesting a long-time depth for the cognitive basis of such engagement. However, the scale of human involvement with material culture by far outstrips anything known from other animal species

both quantitatively and qualitatively. Furthermore, this scale has increased dramatically during hominin¹ evolution in the *ca* 2.5 Myr since the oldest known stone technologies (Semaw *et al.* 1997; Gamble 2007).

Collaboration between neuroimagers and archaeologists has the potential to illuminate the process by which hominins developed this uniquely human capacity for engagement with material culture. Both disciplines have recently advanced by emphasizing the fundamentally embodied character of cultural transmission and it is in this area that dialogue promises to be most fruitful. But this exchange of views will only be achieved if archaeologists first address some conceptual issues.

2. WHAT NEEDS TO CHANGE IN THE STUDY OF HUMAN EVOLUTION

The study of human evolution remains committed to a Cartesian model of cognition and consciousness in which the process of thinking is abstracted from its real-world context. Its practitioners are also largely uninterested in theory, even evolutionary theory (Foley 2001, p. 5), relying instead on sequence and correlation to reveal trends in the data. Archaeologists in particular feel safest with populations (Flannery 1967; Clark 1992) rather than individuals as their unit of study (though see Gamble & Porr 2005), and with a model of rational behaviour based on the economic costs of procuring food. How the food quest was organized leaves tangible traces—camps, tools and residues from foraging and agriculture—and these serve as proxies for variation in reproductive success between species such as Neanderthals and modern humans, and for distinguishing between such problematic economic categories as hunters and farmers.

Similar proxies are used to document the trend in cognitive ability. Here the Cartesian model is most

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evident through the notion of symbolism and the key role it is thought to play in the human revolution of 50 000 years ago. Chase & Dibble (1987, p. 265) examined the rare 'symbolic' items from Neanderthal archaeology 'with an eye towards assessing the degree to which arbitrary categories and symbols structured behaviours'. They concluded that there was little or no evidence—unsurprising, given that they concentrated on material symbols that can trace an unbroken ancestry from contemporary societies, such as 'figurines' and 'jewellery'. Moreover, when it comes to explaining why such items are commonly encountered after 50 000 years ago and associated with modern humans, the answer is invariably that 'substantial amounts of brainpower' (Henshilwood & Marean 2003; but see McBrearty & Brooks 2000; Zilhao 2007), together with language, were now involved.

In particular, the rational approach, using direct material proxies to identify key behaviours, has failed to deliver much of interest concerning the changing structure of hominin society (Johnson & Earle 1987). By comparison with the extensive literature on ape sociality and cognition (e.g. Barrett & Henzi 2005), a study of hominin social life has barely begun (Mithen 1996; Gamble 1999). The reason is simple; even though hominins had brains two or three times larger than apes, their societies apparently lacked material proxies for social institutions such as markets, assemblies and temples. In the absence of such proxies, it would seem little or nothing can be inferred. Neither does the rational approach have much to say beyond the functional about the history of technology and materials. In this paradigm, artefacts are merely externalized mental constructs.

3. EMBODIED KNOWLEDGE AND IMAGINARY GEOGRAPHIES

In emphasizing the embodied character of cultural transmission, we need to avoid falling into the trap of merely promoting from the opposite direction the mind/body dualism we have just criticized. Rather, the notion of 'embodied knowledge' is used here as a corrective to traditional archaeological approaches that tacitly endorsed the notion of abstract decontextualized cognition. We use the term here in reference both to Gibsonian ambulatory perception, which emphasizes the sensory capacities of the body as the primary means of engagement with the world (Gibson 1979), and to 'embodied', 'extended' or 'distributed' approaches within cognitive science (see Anderson (2003) for review, also Hutchins (2008)), linguistics (Lakoff & Johnson 1980, 1999) and neuroscience (e.g. Maravita & Iriki 2004), all of which suggest that cognition is not an abstract symbolizing process but fundamentally structured by the inescapable fact that the biological processes constituting 'mind' are part of a body which is constantly interacting with the world.

The change we advocate, and that opens up the prospect of a more fruitful collaboration with neuroscience, is the adoption of a relational approach to a much wider set of archaeological data. A relational approach (Gamble 1999, 2007) does not seek to separate hominins from their worlds for analytical

purposes. Instead, the focus of its investigation shifts to the *connections* that constitute them within those worlds. From a relational perspective, the entities themselves—individuals, objects and animals—have no essential qualities *per se* but rather are effects or outcomes of their connectedness (e.g. Law 1999, p. 3; see also Gosden 2008). As such, a relational perspective is not necessarily opposed to or separate from a 'rational' reading of the data, but complementary to it.

The shift in standpoint will allow us to address such issues as the evolution of intentionality and the emotions. We will be able to ask whether these changes selected for social bonds that also functioned as scaffolds for the imaginary cognitive geographies identified by Gallese & Lakoff (2005, p. 9): 'All human beings entertain the capacity to imagine worlds that they have or have not seen before, to imagine doing things that they have or have not done before'. Without such cognitive ability there would, for example, be no archaeology, no interest in human evolution and indeed no humans as we conceive them.

Here we will argue that the ability to create and people such imaginary geographies constitutes a basic hominin rather than exclusively human ability (Gamble 2007). It is not an evidence of either a lately evolved modern mind or a sapient revolution (Renfrew 2008); later developments were instead the outcome of a general shift towards the increasing use of material culture to supplement face-to-face interactions between individuals. Such relational questions do not necessarily require better identified proxies in order to consider hominin social life and material culture—a shift in our conceptual approaches can reveal many new relationships, hitherto obscured from view in the archaeological data by a purely rational approach.

4. WHAT NEEDS ADDRESSING IN HUMAN EVOLUTION

Although embodiment has recently become a topic of interest in archaeology (e.g. Hamilakis *et al.* 2002; Sofaer 2006), for the most part archaeologists have yet to follow up the consequences of departing from a Cartesian approach for a perspective in which knowledge is seen as mapped in our sensory–motor system, and therefore embodied (Gallese *et al.* 2004). One such consequence is that emotions are seen as playing a key role, characterizing the human brain (LeDoux 1998) but always also embodied (Niedenthal 2007). For example, Turner (2000) has argued that positive emotions were pressed into service to facilitate the evolution of more complex social behaviour, with hominin evolution demonstrating a trend away from low sociality and individualism towards more group-oriented social structures, which can be investigated by reference to group size and the scale of hominin groups' imaginary geographies. These developments required conceptual changes within the early learning environment of the infant, with the outcome of selection for these positive emotions leading to 'the expansion of the anterior cingulate gyrus, as the centre for playfulness and mother–infant bonding, (and which) may also have been rewired to produce a more generalized source for

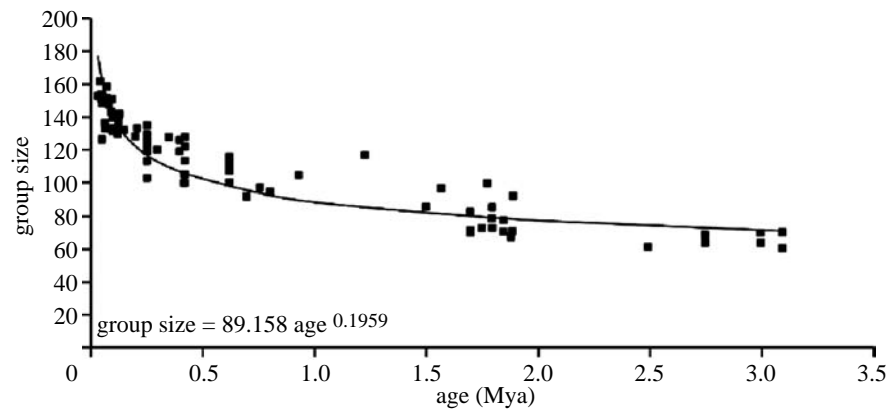


Figure 1. Group sizes predicted for extinct hominins from the strong relationship demonstrated between neocortex ratio and group size among extant primates. Data from Aiello & Dunbar 1993. In fossil hominins, the expansion of the neocortex accounts for the increase in total brain size that can be measured in fossil crania. Mya, million years ago.

happiness and propensities for bonding, altruism, and reciprocity beyond the mother–infant dyad (Turner 2000, p. 112).’

While an admittedly speculative account, Turner’s emphasis on the emotions is suited to a relational rather than strictly rational account of hominin evolution. The task for archaeologists is to integrate material culture into the early learning environments of children. In this context, material culture and emotions do not exist independently; rather, the latter frame experience while the former embodies the concept on which these developing relationships are based.

5. A TIMETABLE TO HOMININ EVOLUTION

The trend in hominin evolution is illustrated here by Dunbar’s social brain model (2003), using increasing group size as a measure of complexity (figure 1).

The model is less concerned with the taxonomy of the various fossils and more with the overall trend in encephalization. Brains are expensive metabolically, and strong selection is required to account for the expansion and the consequent costs involved, e.g. the increased risk of parturition (Aiello 1998). Adaptations for sociality are put forward as one source of such a selective pressure since larger group size brings evolutionary benefits in defence against predators and foraging opportunities through sharing. However, the model is currently light on the mechanisms behind the increased complexity of social life. What were these social bonds and networks based upon and how were they organized into more complex patterns? In particular, what role did material culture play in this trend to complexity?

The earliest stone artefacts are currently *ca* 2.5 Myr old (Semaw *et al.* 1997), thus dating to very early in the process of encephalization. The subsequent evolution of brains and artefacts reflects an entangled history that needs careful unravelling if we are to avoid trite narratives about progress towards modernity. Here, we will structure our discussion of the archaeological data around three processes occurring over the course of hominin evolution.

- (i) A sharp increase in encephalization 500 000 ± 100 000 years ago. This is much earlier than the

artefactual changes that began 300 000 years ago in Africa (McBrearty & Brooks 2000) and gathered pace after 100 000 years ago (d’Errico *et al.* 2003; Henshilwood & Marean 2003). The predicted group sizes at 500 kyr ago probably required language to facilitate interaction (Dunbar 1993). Of interest at this time are life-history changes and the evolution of early learning environments of childhood and the extent to which these were critical to cultural transmission.

- (ii) The global human diaspora (Gamble 1993; Cavalli-Sforza & Cavalli-Sforza 1995), starting with the first appearance of *Homo erectus* (*sensu lato*) outside Africa *ca* 1.7 Myr ago and continuing even after the arrival of ocean-going modern humans in Australia *ca* 60 000 years ago (Gamble *in press*). To what extent does this diaspora depend on the ability to construct imaginative geographies that also supported distributed social networks?
- (iii) The widespread appearance of sedentism and then agriculture 15 000–8000 years ago, which changed human experience in ways that some believe was fundamental for the modern mind (Cauvin 2000; Renfrew 2001; Watkins 2004b). However, sedentism needs to be understood in the context of the social networks and small-world societies that supported them. A comparative approach must look at both sides of this apparent divide.

These processes are emphatically *not* revolutions (Gamble 2007). Nor do we necessarily consider them to be *the* three ‘big events’ in hominin evolution; we simply use them here as temporal markers to organize a long-term perspective based on archaeological evidence. Discussing each in turn, we will demonstrate that all are underpinned by changing social relationships between hominins—and, crucially, between hominins and the material world—building on a basic hominid cognitive repertoire expanded during hominin evolution through the spinning of networks of social relationships that link us over increasing distances through space and time.

6. ENCEPHALIZATION, CHILDHOOD AND CULTURAL AND SOCIAL TRANSMISSION

The concepts of children and childhood are a good example of the kinds of crucial information that rational approaches to hominin evolution often overlook. Children are an almost invisible category in archaeology (Derevenski 2000) and particularly so during hominin evolution. We can find their tiny footprints (Roveland 2000), on occasion their skeletons and very rarely their weaning foods (Mason *et al.* 1994), but further proxies such as cradles, carrying slings and pacifiers are absent. The rational approach assumes, quite reasonably, that they were present (they are, after all, themselves a proxy for reproductive success, the ultimate evolutionary goal). However, it regards them as uninvestigatable, much like the study of hominin society before art, monumental architecture and ball courts (Childe 1951, p. 85; Leach 1973; Gamble 1999, pp. 1–7; Wobst 2000, p. 43).

And yet the mother–child dyad, along with adult pair bonding, is one of the principal units in the construction of hominid social life. Social relationships are the medium and mode of cultural transmission, providing the networks along which ‘objects’ disseminate, and it is in childhood that the bases for these relationships, so crucial to cultural transmission, are established.

New research is beginning to demonstrate how the mirror neuron system informs on the mechanisms of cultural transmission; the information necessary to imitate the acts—and infer the intentions—of others is immediately present in their actions as spectators’ mirror neuron systems automatically map the observed actions onto their own motor systems in logically entrained sequences of action (Gallese *et al.* 2004, 2007). One point of interest here is *how* such sequences become entrained. One hypothesis is that it occurs by repeatedly experiencing sequences of actions ‘as they are habitually performed or observed in the social environment’ (Gallese *et al.* 2007, p. 137).

It follows that, while the neural mechanisms behind imitation and transmission are innate (Gallese *et al.* 2007, p. 145), they are only part of a complex of biological, ethological and social factors that are necessarily related to its evolution. Skeletal and locomotive adaptations such as the size and pelvic orientation of a bipedal hominid mean that increased brain size must be associated with secondary altriciality and delayed maturity, with a concomitant temporal extension of the time available for enculturation and enskillment (see Smith & Tompkins 1995; Grove & Coward submitted), as most cultural transmission occurs vertically, i.e. from parents to children² (Shennan & Steele 1999; Hosfield *in press*). The derived pattern of human life history also includes a substantial period of post-reproductive life, an innovation that makes little sense outside a way of life where the handing down of complex skills learnt over a lifetime is adaptive (Peccei 1995; Hawkes *et al.* 1998; O’Connell *et al.* 1999). Moreover, encephalization is also related to a reduction in the size of the gut and an increase in the proportion of meat in the diet (Aiello & Wheeler 1995). Exploitation of meat, a high-quality patchy food, is associated with larger range sizes and

social groups and necessarily more complex skills for its appropriation which must be learned by each new generation (Foley & Lee 1991; Smith & Tompkins 1995). On a less rational note, hunting is also necessarily associated with new forms of social relationships forged through communal hunting strategies and/or division of labour, and the sharing of large ‘packets’ of meat too substantial for individuals to consume alone.

What lies at the heart of all of these changes is sociality; the relationships between individuals and the mechanisms by which those bonds are initiated and sustained. At the fine scale of individual imitation and transmission, these same relationships also underpin cultural transmission. At a larger scale, innovations and varied forms of material culture are disseminated in a manner analogous to genes (e.g. Boyd & Richerson 1985; Shennan 2002); but again, these practices are part and parcel of the wider social networks that link individuals and communities in space and time, as we will discuss later in relation to agriculture, sedentism and small worlds.

As Fonagy *et al.* (2007, p. 297) propose, ‘evolution has left it to the intimate relationships of early childhood to elaborate the capacity for social cognition fully’. They argue that the capacity of the brain to adapt to ever more challenging physical and social environments cannot be fixed by genetics (see also Deacon (1997) and discussion in Grove & Coward (submitted)). Instead, such adaptation is facilitated for the infant during a prolonged childhood by a group of trusted adults, many of whom will be kin, what they call attachment figures (see also Frith 2008).

Elsewhere, one of us (Gamble 2007, pp. 225–230) has introduced the concept of the childscape, the environment for growth, which consists not only of attachment figures but also emotionally charged arrays including items of material culture. As Hespos & Spelke’s (2004) work with five-month-old babies demonstrates, the significance of these material arrays is that infants think first in material rather than linguistic categories, and establish the relationships between forms³ in an experiential metaphorical manner (Bloom 2004); a good example of knowledge structured by the embodied nature of experiential learning. A relational approach interested in considering children in an evolutionary context does not therefore need child-like material proxies. Instead, it begins with the proposition that the individual is emotionally connected to materials and carers from the first. Moreover, as neuroscience shows, a rigid distinction between body and brain is counterproductive for an understanding of the evolving structure of this cognitive attachment (Gallese *et al.* 2004, 2007; Rizzolatti & Craighero 2004; Gallese 2006; Fonagy *et al.* 2007). In the same way, a division between objects and persons can also be rejected as both are targets for the emotional association, or agency (Gell 1998; Gosden & Marshall 1999; Dobres & Robb 2000), that drives the connections between them—the object of interest in a relational approach. In a relational approach, objects and people are not distinguished by some prior ‘essence’ but as a result of the web of relationships each is a part of (e.g. Law 1999); from this

perspective, people can be considered as a particular category of ‘thing’ with their own characteristic properties or affordances (Gibson 1979; Strathern 1998; Jordan 2008).

7. IMAGINATIVE GEOGRAPHIES, GLOBAL DIASPORAS AND DISTRIBUTED NETWORKS

Among primates—and so probably also among our ancestors, the australopithecines—the primary mechanism for negotiating these social relationships is grooming. The downside, as Dunbar has pointed out, is that any individual can groom only one other individual at a time. In contrast, auditory resources such as vocal chorusing, laughter, singing and speech can be directed towards several individuals simultaneously, and could therefore have been used to sustain groups the size of those predicted for *H. erectus* on the basis of neocortex ratio (figure 1; Dunbar 1993). Dunbar’s work further suggests that these auditory resources are likely to have increased in complexity over time: archaic *sapiens* groups, predicted to be larger again, would need more complex forms of social ‘language’, while *Homo sapiens* extremely large group sizes need the time-and-energy-efficient resources of metaphorical language to sustain them (Dunbar 1993).

But there has been a shift away from a focus on the semiotic content of speech recently, with researchers emphasizing instead its basis in embodied experience (Lakoff & Johnson 1980; see also Rizzolatti & Craighero 2004; Gallese & Lakoff 2005; Gallese *et al.* 2007; Roepstorff 2008). Not only is it argued that language itself may arise from individuals’ common embodied experience, but it has also been recognized that much of the meaning in any instance of conversation is conveyed by fundamentally corporal cues including stance, bodily movement, facial expression, prosody and intonation, which also underpin joint attention, attunement and intentionality (Rizzolatti & Craighero 2004; Mithen 2005; Knoblich & Sebanz 2008).

But of course corporal and auditory resources, if indeed we can separate them out, are not the only social resource that we have to draw on in our social projects. If they were, there would not be much of an archaeological record. We also have *things*: material resources. And while there are spatial and temporal limits beyond which we cannot hear someone trying to talk to us, or see them to judge their conversational stance, material resources persist in both time and space. As one of us has argued (Gamble 1998), this is what allows the extension of social networks beyond the spatial and temporal limitations of individual physical bodies and instances of interaction, and was a key mechanism of the global diaspora of modern humans.

In addition to the long-term temporal trend in vocal and linguistic resources discussed by Dunbar, therefore, there is also a spatial dimension to social relationships: different resources are necessarily associated with very different geographical scales of interaction and relationship. Corporal, embodied strategies such as grooming are practicable only in situations of co-presence, while auditory resources such as speech allow interaction with others within

hearing distance. Material resources, however, can travel considerable distances in both space and time.

It is important to emphasize that each new social resource does not replace but adds to those previously used, so that embodied, vocal material and symbolic resources all become interlinked in the practice of everyday life. However, what we so seem to see during hominin evolution is the gradual adoption of material resources to complement our primate heritage of corporal and emotional social strategies.

A good example is provided by Inuit Inuksuit (singular Inuksuk). These waymarking cairns constructed through the Arctic, like such cairns elsewhere across the globe, have multiple ‘uses’. They act as markers for human paths and animal migration routes, to signal nearby peoples, special places, caches, etc. These structures are maintained with great care; tellingly, they are often constructed to resemble humans, and the word in fact means something that ‘acts in the capacity of a human’ (Hallendy 2000; Varney Burch 2007). Some Inuksuit date back generations, and specific examples are mentioned in the Aya-yait (Varney Burch 2007), the travelling songs passed between generations that help the travellers remember the series of directions involved in long trips in the absence of memorable natural waymarks in Arctic environments. The sameness of snow-bound landscapes, the quality of light and the extremes of weather that often result in ‘white-outs’ where visual cues to direction and movement are virtually non-existent mean that moment-to-moment navigation occurs by almost unconscious reading of the subtle alignments of snow, ice and wind: ‘there is no line separating Earth and sky; there is no intermediate distance, no perspective or contour; visibility is limited; and yet there is an extraordinarily fine topology that relies not on points or objects but rather on haeccities, on sets of relations (winds, undulations of snow... the creaking of ice...)’ (Deleuze & Guattari 1987 (2004), p. 421).

Children must be enculturated, or enskilled through an ‘education of attention’ in Ingold’s terms (2000), into an understanding of this world through a guiding of their bodily experience of it (the use of corporal, emotional resources) as well as through discursive means such as the rote learning and repetition of the Aya-yait travelling songs (auditory resources) which refer specific Inuksuk (material resources) as nodes in the topology of movement and interaction.

Further examples might include the relational material ‘maps’ of Australian Aborigines and Polynesian and Micronesian groups. The Aboriginal spear-thrower illustrated by Ingold (2000, p. 368) and the ‘wave-and-wind’ charts of the Micronesian Marshall Islanders (Turnbull 1991) are material resources that are similarly complemented by and work in tandem with corporal and less material resources: the embodied, enskilled experience of moving through the land- or seascape, and the myths and narratives associated with such journeys—for example, the stories of the dreamtime. These narratives contribute to the transmission of these skills by associating the landscape, its paths, tracks, denizens and the temporality and skills that structure it with known mythical persons, such that knowledge of it becomes *personal*, a question of relationships between individuals. Landscape (and

seascape), paths and routes become integrated into social topologies rather than cognitive maps, and the traversing of them is better viewed as the enactment of a narrative than as an exercise in Cartesian geography.

Although these examples are all drawn from modern human groups, they do serve to illustrate how children are enskilled into the use of the different forms of social resource that function together in the negotiation of a variety of landscapes.

However, even this more relational perspective on material resources remains rather Cartesian in its division of subject and object. One of the most striking features of human life is the extent to which we interact with entities other than our fellow humans, and one of the most lively debates in archaeology concerns the status of material culture—as object or as subject, passively imitated, used, traded, etc., or as playing an active, reflexive role in these practices (Kopytoff 1986; Tilley 1996; Gosden & Marshall 1999; Wobst 2000; Ingold 2002; Jones 2002).

The question of whether objects have agency is too broad an issue to address here. We will also leave aside the problem of semiotic meaning: objects may or may not have agency or ‘meaning’ *per se*, and archaeologists may or may not ever be able to approach that (Tilley 1993; Knappett 2005). But what we can do is to investigate the *effect* of material culture (Conkey 1995; Gosden 2001, p. 164; Coward & Gamble *in press*). The foregoing are rather practical examples of culturally transmitted skills and material culture that allow geographical and temporal extension, but ethnographical and anthropological literature has long demonstrated how objects become integrated into social relationships. They may be invested with great personal and emotional significance, to the point of being considered intentional, living subjects (Kopytoff 1986; Strathern 1988; Hoskins 1998; Coward & Gamble *in press*). For example, Inuit retain a strong emotional attachment to those Inuksuit believed to have been constructed by their ancestors (Varney Burch 2007). The wealth of mnemonic, metaphorical and metonymic references that derives from the biographies of items of material culture thus has the effect of connecting people together across the landscape (Gosden & Marshall 1999; Chapman 2000; Coward & Gamble *in press*). In this light, for example, a necklace such as those found in Upper Palaeolithic graves at Aven des Iboussieres and St-Germain-de-la-Rivière in France becomes a set of metonymic references to the red deer of whose canines it is composed; a mnemonic for the occasions of hunting, trade and/or exchange that brought these together; and metaphorical of the relationships with those people with whom one engaged in these interactions and the places and occasions when these took place (d’Errico & Vanhaeren 2002; Vanhaeren & d’Errico 2005).

For this reason, we would very much like to see neurology investigate not just the physical dimensions of primate and human interaction with items of material culture, but how these relate to the emotional and mnemonic significance of particular objects. Mirror neuron research demonstrates an innate, embodied response to other individuals’ motor actions

among primates: canonical neurons appear to represent not only goal-directed actions but also the potential for such actions based on the objects to hand (Grèzes & Decety 2002; Grèzes *et al.* 2003). The mirror neuron literature would thus appear to confirm that the ‘affordances’ of an item of material culture are directly perceived by an observer (Gallese 2000), as Gibson (1979) had previously argued, and therefore that perception is always immediately and pre-consciously integrated into embodied, active projects. In this way, the object itself can perhaps be seen as providing affordances for embodied action, a possibility that invites some interesting questions about the ways in which the perception of material objects relates to the cultural transmission of manufacture and use.

8. AGRICULTURE, SEDENTISM AND SMALL WORLDS

We have established, then, that social relationships are the *sine qua non* of cultural transmission and, among humans at least, objects of material culture become incorporated in these relationships, enabling their temporal and geographical extension beyond the here-and-now of primate sociality. However, the varying properties of different kinds of material culture both constrain and enable different kinds of activities, inviting some uses and precluding others (Parker-Pearson & Ramilisonina 1998; Tilley 2004). In addition, different individuals will always operate in different contexts with different resources to hand and, as a result, will necessarily construct for themselves very different material networks. But, at the same time, individuals are also always part of groups with shared histories and shared understandings about the appropriateness or otherwise of particular practices and performances. These cross-cutting trends are what result in the varyingly patterned co-associations of different kinds of material resources that are understood archaeologically as ‘cultures’.

The nature of the networks of social relationships between individuals and groups is thus a crucial determinant of the archaeological patterning of material culture—indeed, given the arguments for the active role of material culture in the forging and maintenance of these networks, the archaeological record is best seen as *part of*, and not a passive reflection of, those social networks. The links between the nodes, represented by shared items of material culture, may be forged directly by the transport, trade, exchange, etc. of objects; alternatively they may represent imitation or dissemination of the technologies or ideas behind them. Either way, they document a link, a relationship, between nodes. So the various elements of material culture that are held in common between sites become the heterogeneous relationships connecting the individual elements into multiple interlinked networks. And in this way, a social network perspective can potentially take us from the patterning of things to the structuring of relationships, as called for by Barrett (2000 (1988), p. 28).

One of us (F.C.) is currently using a social network perspective to address the shift to increasingly sedentary ways of life and the gradual adoption of stone-built

architecture in the Near East during the Epipalaeolithic and Early Neolithic (*ca* 18 000–*ca* 8000 radiocarbon years BP). Considerable importance has been attached to the first appearance of permanent built structures as implying a relative fixity of social patternings that may persist between generations, acting as an external form of enculturation and ‘symbolic storage device’ and sparking a new form of cognition among sedentary agriculturalists (e.g. Renfrew 1998; Watkins 2004*a,b*). However, there are no straightforward associations between mobility, unstructured use of space and hunting and gathering on the one hand, and permanent architecture, sedentism and the symbolic or structured use of space on the other hand: there are, for example, mobile agriculturalists, mobile hunter–gatherers who cultivate plants and sedentary hunter–gatherers (e.g. Terrell 2007).

Each of these groups clearly has very different ways of thinking about using and structuring space that vary from the immaterial and ephemeral through to the physical and semi-permanent. Cribb’s (1991) study comparing pastoral tent dwellings and village houses in Turkey found that, despite the obvious differences in the building materials used, the tent and the house were virtually identical in their underlying organizational templates. There is nothing necessarily ‘unstructured’ about the kinds of non-permanent constructions used by mobile peoples: even just the placing of sticks in the ground to represent a ‘doorway’ acts to structure movement and activity along gender and age lines in temporary !Kung encampments (Whitelaw 1994, p. 217). Nor are the stone-built constructions of the Neolithic necessarily ‘permanent’ *per se*: sites and houses in the Epipalaeolithic and Early Neolithic demonstrate continuous maintenance, reworking and remodelling, burning, rebuilding, abandonment and reuse. As Prussin (1989, p. 141) reminds us, ‘The concept ‘temporary’ is not synonymous with ‘transient’; the concept of ‘permanent’ is distinct from ‘stationary’.

We prefer to view the gradual shift in the forms and materialities of structures as integral to the social relationships of which they were a part—a response to a different social context in which people used alternative resources to approach some new social problems relating to the changing scale of their worlds. Constructed environments—whether primate ‘nests’ (Groves & Pi 1985; Kolen 1999) or Pre-Pottery Neolithic B (PPNB) houses—have a very obvious effect on the distribution and trajectories of bodies in space that is a fundamental part of the negotiation and practice of social relationships (Hillier & Hanson 1984; Barrett 1994). The layout and construction of houses is often referenced to the body (Carsten & Hugh-Jones 1995), to the extent that they form a material metaphor for the experience of living and being social (Hodder 1990; Tilley 1999).

However, this experience is not the same for everyone, everywhere. As the scale and diversity of the social relationships involved increases—as it did, dramatically, during the global diasporas detailed in the previous section—such experience may diverge widely. While the basic cognitive mechanisms discussed above, supported by material culture, make it possible in theory to establish social relationships with

anyone, in practice it may be extremely difficult to find a common denominator from which to commence social interaction.

In mobile groups, the networks of social relationships are diffuse, open and ephemeral, shifting and changing almost constantly as groups and individuals break up and aggregate. But the basic unit is small and structured around groups of very close kin, who all know each other extremely well (Lofland 1973; Wilson 1988; Whitelaw 1991). The individual performances of social interaction are face-to-face, personal. They use corporal resources: bodily movement and expression, and intimate conversational stances (Hillier & Hanson 1984; Wilson 1988).

In less mobile groups, the option of fissioning, of breaking away from the group, becomes less feasible almost by definition. And as the number of individuals in any group increases, there is of course an exponential increase in the inter-individual relationships that are possible. But these social ties take time and energy to maintain, and they are also cognitively demanding in terms of integrating the relevant social information (Dunbar 1992, 1993, 2003; Gamble 1999; Watts 2003). It is simply not possible for everyone to have the kind of strong, complex relationship that characterizes kin relationships with everyone else in the same society. In larger groups, therefore, individual relationships become simplified, reducing the potential ‘overload’ of information (Lofland 1973), so that the relationships between people have fewer dimensions, being categorized according to a few key characteristics. Thus, knowledge of others whom you meet only in very particular contexts is *categorical* rather than simply biographical (Granovetter 1973, 1983; Lofland 1973; Milgram 1977; Rapoport 1981; Milroy 1987, cited Gamble 1996; cf. Bloch 2008).

Thus, in high-density, strongly linked small-scale groups such as extended families, the behaviours and performances appropriate to particular temporal and spatial contexts are so well known, and activities so highly routinized, that people do not need much in the way of clues from their environment to tell them how to act (Douglas 1973, p. 78; Coser 1975; Rapoport 1990). For example, in many Australian Aboriginal camps, sweeping the ground around the shelter two or three times a day to alter its surface texture is enough to indicate a private domain (Rapoport 1990, p. 16). In larger scale, less-dense societies, however, it becomes necessary to create specialized ‘settings’ to cue appropriate behaviour, so that contemporary western dwellings may have fences, paths, porches and several doors and gates to achieve the same goal of indicating privacy (Rapoport 1990, p. 16). Increasing social scale is accompanied by increasing redundancy of performative cues through the elaboration of material environments that compensate for weak or ‘categorical’ knowledge of the people with whom one must interact (Rapoport 1969, p. 30; Granovetter 1973, 1983; Lofland 1973; Bernstein cited Coser 1975; Donley-Reid 1990, p. 115; Kent 1990; Sanders 1990, p. 71; Whitelaw 1991, p. 165, 1994, p. 238).

Such a shift to increasingly well-defined material and social environments has long been considered characteristic of the Epipalaeolithic and Early Neolithic of the Near East (see Renfrew 1998; Watkins 2004*a,b*; Runciman 2005). However, the alternative model

suggested here posits that instead of a step change, material resources such as permanent built structures were incorporated gradually into social practices as the scale of social life increased; a social network perspective will allow testing of this hypothesis through quantitative analysis of the near eastern Epipalaeolithic and Early Neolithic.

Clearly, corporal and material resources are not mutually exclusive: even today, we use corporal resources, very intimate body-based forms of interaction, alongside our more formal architectures. Small- and large-scale forms of sociality intersect and interlace, grading into and becoming layered onto one another. Nevertheless, it would seem that as groups and societies increase in scale, material resources become more and more essential to maintain social relationships with others who are becoming increasingly 'distant' in social and physical space.

9. CONCLUSION: THE SAPIENT BODY AND THE MIND OF THE ARTEFACT

The challenge that faces the long-term study of hominin evolution is to understand how 'the mind' is grounded in real-world contexts. A concerted effort by neuroscientists and archaeologists working together may provide a fundamental insight into the mechanisms of social life and how this structures our relationships not only with other people but also with material culture.

We have focused here on three trends in hominin evolution: rapid encephalization; a global diaspora; and the built environment. Our argument is that the sapient mind is best approached through the study of local and immediate cultural transmission, which is always necessarily *social* transmission, grounded first and foremost in the social relationships forged between individuals and between groups using the different kinds of resources available to hand.

We have argued that the rapid encephalization seen among early hominins is intimately related to a deepening of social relationships between individuals, enacted using the intimate, face-to-face social resources that are our primate inheritance. The changes in hominin life-history and metabolic budgets clearly reflect selection for a way of life in which the construction and maintenance of social bonds through the incorporation of material culture into our social networks is of primary importance.

The extension of these social relationships in time and space built on this increasing engagement with material culture was marked by the commencement of a phase of rapid geographical expansion. Using material objects to forge and maintain imaginary geographies that spanned the globe, hominins could navigate their way across the world as well as among each other—hence, the scale and diversity of material culture of the last 100 000 years (Gamble 2007, ch. 7).

Seen in this light, the gradual development of Neolithic *Homo urbanus* marks not so much a new state of mind as an increasingly fine-tuned ability to manipulate social networks over these great temporal and geographical scales using a variety of resources, but increasingly reliant on material objects and environments in a world where increased geographical distance was accompanied by much greater social distance.

Through neuroimaging studies, we are beginning to understand some of the cognitive mechanisms that underpin the corporal social resources used in face-to-face interactions among hominins as well as among primates and humans. But, the evolutionary question remains: how are such interactions 'scaled up' in time and space to allow, for example, global diasporas and small worlds? We have argued here that these developments are best explained by the adoption and the increasing use of material resources, and to that end our interest is in the neurological mechanisms for emotional and social investment in material culture.

Artefacts do not have minds of their own. But neither do people. Both are caught up from the first in networks of action that are the basis for our ability to people the world, live in settled communities and diversify our material worlds beyond anything known to other species. The selective pressures and the mechanism for doing so came from the social relationships that underpin our imaginary geographies and make our minds so distinctive. However, these relationships are dependent not only on face-to-face interactions between individuals, a basic primate strategy, but also on the active incorporation of material culture into those relationships.

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ENDNOTES

¹Hominins include ourselves (humans) and all our fossil ancestors, while hominids include humans, hominins and the great apes.

²Cultural transmission can also be horizontal and oblique (for example, within or between peer groups) or formal or informal (formal education or apprenticeships versus more or less discursive forms of childhood enskillment; Boyd & Richerson 1985).

³These were the fit between a ring and a post or a cylinder and a container; examples of instruments and containers (see Gamble (2007) for further discussion).

REFERENCES

- Aiello, L. C. 1998 The 'expensive tissue hypothesis' and the evolution of the human adaptive niche: a study in comparative anatomy. In *Science in archaeology: an agenda for the future* (ed. J. Bayley), pp. 25–36. London, UK: English Heritage.
- Aiello, L. C. & Dunbar, R. 1993 Neocortex size, group size and the evolution of language. *Curr. Anthropol.* **34**, 184–193. (doi:10.1086/204160)
- Aiello, L. C. & Wheeler, P. 1995 The expensive-tissue hypothesis: the brain and the digestive system in human and primate evolution. *Curr. Anthropol.* **36**, 199–221. (doi:10.1086/204350)
- Anderson, M. L. 2003 Embodied cognition: a field guide. *Artif. Intell.* **149**, 91–130. (doi:10.1016/S0004-3702(03)00054-7)
- Barrett, J. C. 1994 Defining domestic space in the Bronze Age of southern Britain. In *Architecture and order: approaches to social space* (eds M. Parker-Pearson & C. Richards), pp. 87–97. London, UK: Routledge.

- Barrett, J. C. 2000 [1988] Fields of discourse: reconstituting a social archaeology. In *Interpretive archaeology* (ed. J. Thomas), pp. 23–32. London, UK: Leicester University Press.
- Barrett, L. & Henzi, P. 2005 The social nature of primate cognition. *Proc. R. Soc. B* **272**, 1865–1875. (doi:10.1098/rspb.2005.3200)
- Bloch, M. 2008 Why religion is nothing special but is central. *Phil. Trans. R. Soc. B* **363**, 2055–2061. (doi:10.1098/rstb.2008.0007)
- Bloom, P. 2004 Children think before they speak. *Nature* **430**, 410–411. (doi:10.1038/430410a)
- Boyd, R. & Richerson, P. J. 1985 *Culture and the evolutionary process*. Chicago, IL: University of Chicago Press.
- Carsten, J. & Hugh-Jones, S. (eds) 1995 *About the house: Lévi-Strauss and beyond*. Cambridge, UK: Cambridge University Press.
- Cauvin, J. 2000 *The birth of the gods and the origins of agriculture*. Cambridge, UK: Cambridge University Press.
- Cavalli-Sforza, L. L. & Cavalli-Sforza, F. 1995 *The great human diasporas: the history of diversity of evolution*. Reading, MA: Perseus Books.
- Chapman, J. 2000 *Fragmentation in archaeology: people, places and broken objects in the prehistory of south eastern Europe*. London, UK: Routledge.
- Chase, P. G. & Dibble, H. 1987 Middle Palaeolithic symbolism: a review of current evidence and interpretation. *J. Anthropol. Archaeol.* **6**, 263–293. (doi:10.1016/0278-4165(87)90003-1)
- Childe, V. G. 1951 *Social evolution*. London, UK: Watts.
- Clark, G. A. 1992 A comment on Mithen's ecological interpretation of Palaeolithic art. *Proc. Prehist. Soc.* **58**, 107–109.
- Conkey, M. W. 1995 Making things meaningful: approaches to the interpretation of the Ice Age imagery of Europe. In *Meaning in the visual arts: views from the outside. A centennial commemoration of Erwin Panofsky* (ed. I. Lavin), pp. 49–64. Princeton, NJ: Institute for Advanced Study, Princeton University Press.
- Coser, R. 1975 The complexity of roles as seedbed of individual autonomy. In *The idea of social structure: essays in honor of Robert Merton* (ed. L. Coser), pp. 236–263. New York, NY: Harcourt Brace Jovanovich.
- Coward, F. & Gamble, C. In press. Materiality and metaphor in earliest prehistory. In *The cognitive life of things* (eds C. Renfrew & L. Malafouris). Cambridge, UK: Macdonald Institute Monographs.
- Cribb, R. 1991 *Nomads in archaeology*. Cambridge, UK: Cambridge University Press.
- Davidson, I. & McGrew, W. C. 2005 Stone tools and the uniqueness of human culture. *J. R. Anthropol. Inst.* **11**, 793–817. (doi:10.1111/j.1497-9655.2005.00262.x)
- Deacon, T. 1997 *The symbolic species: the co-evolution of language and the human brain*. London, UK: Allen Lane.
- de Amoura, A. C. & Lee, P. C. 2004 Capuchin stone tool use in Caatinga dry forest. *Science* **306**, 1909. (doi:10.1126/science.1102558)
- Deleuze, G. & Guattari, F. 1987 (2004) *A thousand plateaus: capitalism and schizophrenia*. London, UK: Continuum.
- Derevenski, J. S. (ed.) 2000 *Children and material culture*. London: Routledge.
- d'Errico, F. & Vanhaeren, M. 2002 Criteria for identifying red deer (*Cervus elaphus*) age and sex from their canines. Application to the study of Upper Palaeolithic and Mesolithic ornaments. *J. Archaeol. Sci.* **29**, 211–232. (doi:10.1006/jasc.2001.0687)
- d'Errico, F. et al. 2003 Archaeological evidence for the emergence of language, symbolism, and music: an alternative multidisciplinary perspective. *J. World Prehist.* **17**, 1–70. (doi:10.1023/A:1023980201043)
- Dobres, M.-A. & Robb, J. 2000 *Agency in archaeology*. London, UK: Routledge.
- Donley-Reid, L. W. 1990 A structuring structure: the Swahili house. In *Domestic architecture and the use of space: an interdisciplinary cross-cultural study* (ed. S. Kent), pp. 114–127. Cambridge, UK: Cambridge University Press.
- Douglas, M. 1973 *Natural symbols*. Harmondsworth, UK: Pelican Books.
- Dunbar, R. I. M. 1992 Neocortex size as a constraint on group size in primates. *J. Hum. Evol.* **20**, 469–493. (doi:10.1016/0047-2484(92)90081-J)
- Dunbar, R. I. M. 1993 Coevolution of neocortical size, group size and language in humans. *Behav. Brain Sci.* **16**, 681–735.
- Dunbar, R. I. M. 2003 The social brain: mind, language and society in evolutionary perspective. *Annu. Rev. Anthropol.* **32**, 163–181. (doi:10.1146/annurev.anthro.32.061002.093158)
- Flannery, K. V. 1967 Culture history versus cultural process: a debate in American archaeology. *Sci. Am.* **217**, 119–122.
- Foley, R. A. 2001 In the shadow of the modern synthesis? Alternative perspectives on the last fifty years of palaeoanthropology. *Evol. Anthropol.* **10**, 5–15. (doi:10.1002/1520-6505(2001)10:1<5::AID-EVAN1008>3.0.CO;2-Y)
- Foley, R. A., Lee, P. C., Widdowson, E. M., Knight, C. D. & Jonxis, J. H. P. 1991 Ecology and energetics of encephalization in hominid evolution. *Phil. Trans. R. Soc. B* **334**, 223–232. (doi:10.1098/rstb.1991.0111)
- Fonagy, P., Gergely, G. & Target, M. 2007 The parent–infant dyad and the construction of the subjective self. *J. Child Psychol. Psychiatr.* **48**, 288–328. (doi:10.1111/j.1469-7610.2007.01727.x)
- Frith, C. D. 2008 Social cognition. *Phil. Trans. R. Soc. B* **363**, 2033–2039. (doi:10.1098/rstb.2008.0005)
- Gallese, V. 2000 Agency and motor representations: new perspectives on intersubjectivity. *Paper presented at the Workshop on Autism and the Theory of Mind, Lyon, 18 May*.
- Gallese, V. 2006 Embodied simulation: from mirror neuron systems to interpersonal relations. In *Empathy and fairness* (eds G. Bock & J. Goode), pp. 3–19. Chichester, UK: Wiley.
- Gallese, V. & Lakoff, G. 2005 The brain's concepts: the role of the sensory–motor system in conceptual knowledge. *Cogn. Neuropsychol.* **21**, 455–479. (doi:10.1080/02643290442000310)
- Gallese, V., Keysers, C. & Rizzolatti, G. 2004 A unifying view of the basis of social cognition. *Trends Cogn. Sci.* **8**, 396–403. (doi:10.1016/j.tics.2004.07.002)
- Gallese, V., Eagle, M. N. & Migone, P. 2007 Intentional attunement: mirror neurons and the neural underpinnings of interpersonal relations. *J. Am. Psychoanal. Assoc.* **55**, 131–176. (doi:10.1016/j.brainres.2006.01.054)
- Gamble, C. 1993 *Timewalkers: the prehistory of global colonization*. London, UK: Penguin Books.
- Gamble, C. 1996 Making tracks: hominid networks and the evolution of the social landscape. In *The archaeology of human ancestry: power, sex and tradition* (eds J. Steele & S. Shennan), pp. 253–277. London, UK: Routledge.
- Gamble, C. 1998 Palaeolithic society and the release from proximity: a network approach to intimate relations. *World Archaeol.* **29**, 426–449.
- Gamble, C. 1999 *The Palaeolithic societies of Europe*. Cambridge, UK: Cambridge University Press.
- Gamble, C. 2007 *Origins and revolutions: human identity in earliest prehistory*. Cambridge, UK: Cambridge University Press.
- Gamble, C. In press. Kinship and material culture: archaeological implications of the human global diaspora. In *Kinship and evolution* (eds W. James & H. Callan). Oxford, UK: Blackwell.

- Gamble, C. S. & Porr, M. (eds) 2005 *The individual hominid in context: archaeological investigations of Lower and Middle Palaeolithic landscapes, locales and artefacts*, London, UK: Routledge.
- Gell, A. 1998 *Art and agency: an anthropological theory*. Oxford, UK: Clarendon Press.
- Gibson, J. J. 1979 *The ecological approach to visual perception*. Boston, MA: Houghton Mifflin.
- Gosden, C. 2001 Making sense: archaeology and aesthetics. *World Archaeol.* **32**, 163–167. (doi:10.1080/0043824010079226)
- Gosden, C. 2008 Social ontologies. *Phil. Trans. R. Soc. B* **363**, 2003–2010. (doi:10.1098/rstb.2008.0013)
- Gosden, C. & Marshall, Y. 1999 The cultural biography of objects. *World Archaeol.* **31**, 169–178.
- Granovetter, M. S. 1973 The strength of weak ties. *Am. J. Sociol.* **78**, 1360–1380. (doi:10.1086/225469)
- Granovetter, M. S. 1983 The strength of weak ties: a network theory revisited. *Sociol. theory* **1**, 201–233. (doi:10.2307/202051)
- Grèzes, J. & Decety, J. 2002 Does visual perception of object afford action? Evidence from a neuroimaging study. *Neuropsychologia* **40**, 212–222. (doi:10.1016/S0028-3932(01)00089-6)
- Grèzes, J., Armony, J. L., Rowe, J. & Passingham, R. E. 2003 Activations related to “mirror” and “canonical” neurons in the human brain: an fMRI study. *Neuroimage* **18**, 928–937. (doi:10.1016/S1053-8119(03)00042-9)
- Grove, M. & Coward, F. Submitted. From individual neurons to social brains.
- Groves, C. P. & Pi, J. S. 1985 From ape’s nest to human fix-point. *Man (n.s.)* **20**, 22–47.
- Hallendy, N. 2000 *Inuksuit: silent messengers of the Arctic*. Washington, DC: University of Washington Press.
- Hamilakis, Y., Pluciennik, M. & Tarlow, S. 2002 *Thinking through the body: archaeologies of corporeality*. London, UK: Kluwer Academic/Plenum Publishers.
- Hawkes, K., O’Connell, J. F., Jones, N. G. B., Alvarez, H. & Charnov, E. L. 1998 Grandmothering, menopause, and the evolution of human life histories. *Proc. Natl Acad. Sci. USA* **95**, 1336–1339. (doi:10.1073/pnas.95.3.1336)
- Henshilwood, C. S. & Marean, C. W. 2003 The origin of modern human behavior: critique of the models and their test implications. *Curr. Anthropol.* **44**, 627–651. (doi:10.1086/377665)
- Hespos, S. J. & Spelke, E. S. 2004 Conceptual precursors to language. *Nature* **430**, 453–456. (doi:10.1038/nature02634)
- Hillier, B. & Hanson, J. 1984 *The social logic of space*. Cambridge, UK: Cambridge University Press.
- Hodder, I. 1990 *The domestication of Europe: structure and contingency in Neolithic societies*. Oxford, UK: Blackwell.
- Hosfield, R. T. In press. Modes of transmission and material culture patterns in craft skills. In *Pattern and process in cultural evolution* (ed. S. Shennan), Berkeley, CA: University of California Press.
- Hoskins, J. 1998 *Biographical objects: how things tell the stories of people’s lives*. London, UK: Routledge.
- Hutchins, E. 2008 The role of cultural practices in the emergence of modern human intelligence. *Phil. Trans. R. Soc. B* **363**, 2011–2019. (doi:10.1098/rstb.2008.0003)
- Ingold, T. 2000 *The perception of the environment: essays in livelihood, dwelling and skill*. London, UK: Routledge.
- Ingold, T. 2002 The agency of tools. Paper presented at the *Theoretical Archaeology Group (TAG) Conference, University of Manchester, December 2002*.
- Johnson, A. W. & Earle, T. 1987 *The evolution of human societies*. Stanford, CA: Stanford University Press.
- Jones, A. 2002 *Archaeological theory and scientific practice*. Cambridge, UK: Cambridge University Press.
- Jordan, J. S. 2008 Wild agency: nested intentionalities in cognitive neuroscience and archaeology. *Phil. Trans. R. Soc. B* **363**, 1981–1991. (doi:10.1098/rstb.2008.0009)
- Kent, S. 1990 A cross-cultural study of segmentation, architecture and the use of space. In *Domestic architecture and the use of space: an interdisciplinary cross-cultural study* (ed. S. Kent), pp. 127–152. Cambridge, UK: Cambridge University Press.
- Knappett, C. 2005 *Thinking through material culture: an interdisciplinary perspective*. Philadelphia, PA: Pennsylvania University Press.
- Knoblich, G. & Sebanz, N. 2008 Evolving intentions for social interaction: from entrainment to joint action. *Phil. Trans. R. Soc. B* **363**, 2021–2031. (doi:10.1098/rstb.2008.0006)
- Kolen, J. 1999 Hominids without homes: on the nature of Middle Palaeolithic settlement in Europe. In *The Middle Palaeolithic occupation of Europe* (eds W. Roebroeks & C. Gamble), pp. 140–175. Leiden, The Netherlands: University of Leiden Press.
- Kopytoff, I. 1986 The cultural biography of things: commoditization as process. In *The social life of things: commodities in cultural perspective* (ed. A. Appadurai), pp. 64–91. Cambridge, UK: Cambridge University Press.
- Lakoff, G. & Johnson, M. 1980 *Metaphors we live by*. Chicago, IL: The University of Chicago Press.
- Lakoff, G. & Johnson, M. 1999 *Philosophy in the flesh*. New York: Basic Books.
- Law, J. 1999 After ANT: complexity, naming and topology. In *Actor network theory and after* (eds J. Law & J. Hassard), pp. 1–14. Oxford/Keele, UK: Blackwell Publishers/The Sociological Review.
- Leach, E. 1973 Concluding address. In *The explanation of culture change: models in prehistory* (ed. C. Renfrew), pp. 761–771. London, UK: Duckworth.
- LeDoux, J. 1998 *The emotional brain*. London, UK: Orion Books.
- Lofland, L. H. 1973 *A world of strangers: order and action in urban public space*. New York, NY: Basic Books.
- Maravita, A. & Iriki, A. 2004 Tools for the body (schema). *Trends Cogn. Sci.* **8**, 79–86. (doi:10.1016/j.tics.2003.12.008)
- Mason, S., Hather, J. & Hillman, G. 1994 Preliminary investigation of the plant macro-remains from Dolni Vestonice II and its implications for the role of plant foods in Palaeolithic and Mesolithic Europe. *Antiquity* **68**, 48–57.
- McBrearty, S. & Brooks, A. S. 2000 The revolution that wasn’t: a new interpretation of the origin of modern human behavior. *J. Hum. Evol.* **39**, 453–563. (doi:10.1006/jhev.2000.0435)
- McGrew, W. C. 1992 *Chimpanzee material culture: implications for human evolution*. Cambridge, UK: Cambridge University Press.
- Milgram, S. 1977 *The individual in a social world: essays and experiments*. Reading, MA: Addison-Wesley Publishing Company.
- Mithen, S. 1996 *The prehistory of the mind: a search for the origins of art, religion and science*. London, UK: Thames and Hudson.
- Mithen, S. 2005 *The singing Neanderthals: the origins of music, language, mind and body*. London, UK: Weidenfeld and Nicolson.
- Niedenthal, P. M. 2007 Embodying emotion. *Science* **316**, 1002–1005. (doi:10.1126/science.1136930)
- O’Connell, J. F., Hawkes, K. & Jones, N. G. B. 1999 Grandmothering and the evolution of *Homo erectus*. *J. Hum. Evol.* **36**, 461–485. (doi:10.1006/jhev.1998.0285)
- Parker-Pearson, M. & Ramilisonina 1998 Stonehenge for the ancestors: the stones pass on the message. *Antiquity* **72**, 308–326.

- Peccei, J. S. 1995 The origin and evolution of menopause: the altriciality-lifespan hypothesis. *Ethol. Sociobiol.* **16**, 425–449. (doi:10.1016/0162-3095(95)00069-0)
- Prussin, L. 1989 The architecture of nomadism: gabra placemaking and culture. In *Housing, culture and design: a comparative perspective* (eds S. M. Low & E. Chambers), pp. 141–163. Philadelphia, PA: University of Pennsylvania Press.
- Rapoport, A. 1969 *House form and culture*. Eaglewood Cliffs, NJ: Prentice-Hall.
- Rapoport, A. 1981 Identity and environment: a cross-cultural perspective. In *Housing and identity: cross-cultural perspectives* (ed. J. S. Duncan), pp. 6–35. London, UK: Croom Helm.
- Rapoport, A. 1990 Systems of activities and systems of settings. In *Domestic architecture and the use of space: an interdisciplinary cross-cultural study* (ed. S. Kent), pp. 9–20. Cambridge, UK: Cambridge University Press.
- Renfrew, C. 1998 Mind and matter: cognitive archaeology and external symbolic storage. In *Cognition and material culture: the archaeology of symbolic storage* (eds C. Renfrew & C. Scarre), pp. 1–6. Oxford, UK: Oxbow Books.
- Renfrew, C. 2001 Symbol before concept: material engagement and the early development of society. In *Archaeological theory today* (ed. I. Hodder), pp. 122–140. London, UK: Polity Press.
- Renfrew, C. 2008 Neuroscience, evolution and the sapient paradox: the factuality of value and of the sacred. *Phil. Trans. R. Soc. B* **363**, 2041–2047. (doi:10.1098/rstb.2008.0010)
- Rizzolatti, G. & Craighero, L. 2004 The mirror–neuron system. *Annu. Rev. Neurosci.* **27**, 169–192. (doi:10.1146/annurev.neuro.27.070203.144230)
- Roepstorff, A. 2008 Things to think with: words and objects as material symbols. *Phil. Trans. R. Soc. B* **363**, 2049–2054. (doi:10.1098/rstb.2008.0015)
- Roveland, B. 2000 Footprints in the clay: Upper Palaeolithic children in ritual and secular contexts. In *Children and material culture* (ed. J. S. Derevenski), pp. 29–38. London, UK: Routledge.
- Runciman, W. G. 2005 Stone Age sociology. *J. R. Anthropol. Inst.* **11**, 129–142. (doi:10.1111/j.1467-9655.2005.00229.x)
- Sanders, D. 1990 Behavioral conventions and archaeology: methods for the analysis of ancient architecture. In *Domestic architecture and the use of space: an interdisciplinary cross-cultural study* (ed. S. Kent), pp. 43–72. Cambridge, UK: Cambridge University Press.
- Semaw, S., Renne, P., Harris, J. W. K., Feibel, C. S., Bernor, R. L., Fesseha, N. & Mowbray, K. 1997 2.5 Million-year-old stone tools from Gona, Ethiopia. *Nature* **385**, 333–336. (doi:10.1038/385333a0)
- Shennan, S. 2002 *Genes, memes and human History: Darwinian archaeology and cultural evolution*. London, UK: Thames and Hudson.
- Shennan, S. & Steele, J. 1999 Cultural learning in hominids: a behavioural ecological approach. In *Mammalian social learning: comparative and ecological perspectives* (eds H. O. Box & K. R. Gibson), pp. 367–388. Cambridge, UK: Cambridge University Press.
- Smith, B. H. & Tompkins, R. L. 1995 Towards a life history of the hominidae. *Annu. Rev. Anthropol.* **24**, 257–279. (doi:10.1146/annurev.an.24.100195.001353)
- Sofaer, J. 2006 *The body as material culture*. Cambridge, UK: Cambridge University Press.
- Stout, D., Toth, N., Schick, K. & Chaminade, T. 2008 Neural correlates of Early Stone Age tool-making: technology, language and cognition in human evolution. *Phil. Trans. R. Soc. B* **363**, 1939–1949. (doi:10.1098/rstb.2008.0001)
- Strathern, M. 1988 *The gender of the gift: problems with women and problems with society in Melanesia*. Berkeley, MA: University of California Press.
- Strathern, M. 1998 Social relations and the idea of externality. In *Cognitive storage and material culture: the archaeology of symbolic storage* (eds C. Renfrew & C. Scarre), pp. 135–147. Cambridge, UK: McDonald Institute.
- Terrell, J. E. 2007 The rudiments of agriculture and domestication: response to Peter Bellwood's first farmers: the origins of agricultural societies. *Camb. Archaeol. J.* **17**, 100–102. (doi:10.1017/S0959774307000078)
- Tilley, C. (ed.) 1993 *Interpretative archaeology*, London, UK: Berg.
- Tilley, C. 1996 *An ethnography of the Neolithic*. Cambridge, UK: Cambridge University Press.
- Tilley, C. 1999 *Metaphor and material culture*. Oxford, UK: Blackwell.
- Tilley, C. 2004 *The materiality of stone: explorations in landscape phenomenology*. London, UK: Berg.
- Turnbull, D. 1991 *Mapping the world in the mind: an investigation of the unwritten knowledge of Micronesian navigators*. Geelong, Australia: Deakin University Press.
- Turner, J. H. 2000 *On the origins of human emotions: a sociological inquiry into the evolution of human affect*. Stanford, CA: Stanford University Press.
- Vanhaeren, M. & d'Errico, F. 2005 Grave goods from the Saint-Germain-la-Rivière burial: evidence for social inequality in the Upper Palaeolithic. *J. Anthropol. Archaeol.* **24**, 117–134. (doi:10.1016/j.jaa.2005.01.001)
- Varney Burch, J. 2007 Arctic inuit art. See <http://www.arcticinuitart.com/culture/inuk.html>.
- Watkins, T. 2004a Architecture and 'theatres of memory' in the Neolithic of Southwest Asia. In *Rethinking materiality: the engagement of mind with the material world* (eds E. DeMarrais, C. Gosden & C. Renfrew), pp. 97–106. Cambridge, UK: McDonald Institute of Archaeological Research.
- Watkins, T. 2004b Building houses, framing concepts, constructing worlds. *Paléorient* **30**, 5–24.
- Watts, D. J. 2003 *Six degrees: the science of a connected age*. London, UK: Vintage.
- Whitelaw, T. 1991 Some dimensions of variability in the social organisation of community space among foragers. In *Ethnoarchaeological approaches to mobile campsites: hunter-gatherer and pastoralist case studies* (eds C. S. Gamble & W. A. Boismier), pp. 139–188. Ann Arbor, MI: International Monographs in Prehistory 1.
- Whitelaw, T. M. 1994 Order without architecture: functional, social and symbolic dimensions in hunter-gatherer settlement organization. In *Architecture and order: approaches to social space* (eds M. Parker-Pearson & C. Richards), pp. 217–243. London, UK: Routledge.
- Wilson, P. 1988 *The domestication of the human species*. New Haven, CT: Yale University Press.
- Wobst, H. M. 2000 Agency in (spite of) material culture. In *Agency in archaeology* (eds M.-A. Dobres & J. Robb), pp. 40–50. London, UK: Routledge.
- Zilhao, J. 2007 The emergence of ornaments and art: an archaeological perspective on the origins of behavioural "modernity". *J. Archaeol. Res.* **15**, 1–54. (doi:10.1007/s10814-006-9008-1)