Special Section
Steps to a 'Neuroarchaeology' of Mind, part 1

Introduction

Lambros Malafouris & Colin Renfrew

Recent breakthroughs in the cognitive and brain sciences, most importantly developments in neuroimaging technologies including functional magnetic resonance imaging (fMRI), positron emission tomography (PET), event-related potential (ERP), and magnetoencephalography (MEG), have opened a new window on the human mind and offered a whole new set of possibilities for exploring its hidden functional architecture. This growing analytic potential can also be seen reflected in the numerous new fields of research, ranging from neuroethics and neuroprosthetics to the latest emerging field of neuroeconomics, which each year are being added to the rapidly expanding domain of contemporary cognitive and brain sciences. Despite these important developments however, within archaeology there has been little awareness of the challenging questions constantly arising from current findings in this field. With a few recent exceptions in the areas of cognitive archaeology and evolutionary neuroscience (e.g. Stout *et al.* 2000; Stout & Chaminade 2007; Dehaene *et al.* 2005; Frey 2003; 2004; 2008; Bruner 2003; 2004; Gibson 1993; Wynn & Coolidge 2003; 2004; Coolidge & Wynn 2004; 2005; Deacon 1997; Hodgson & Helvenston 2006; Mithen 2005), no systematic attempt has been made to channel this huge emerging potential in the direction of a common integrated research program targeting the big picture of human cognitive evolution (both before and most importantly after the so-called speciation phase) (but see Renfrew *et al.* 2008). Although archaeologists do not excavate neural tissue, we should bear in mind that the development of functional neuroimaging has allowed the investigation of a whole new set of questions which raise a host of archaeological and anthropological issues and thus demand our attention and critical evaluation. The time seems to be ripe for archaeology to start responding to, and engaging with, this emerging and rapidly expanding field of neuroscientific research. The aim of this special section is precisely to stimulate a more systematic reflection on neuroscience's claims. In particular our main objectives are: a) to promote the understanding of some key recent developments in neuroscience; b) to articulate some of the possible questions and approaches that can be seen as emerging at the interface between cognitive/social archaeology and cognitive/social neuroscience; and c) to investigate the possible role and contribution of archaeological and anthropological research to key debates within the neurosciences. This special two-part section of the *Cambridge Archaeological Journal*, issues 18.3 and 19.1 presents a sampling of current results, ongoing work and future prospects of such a multidisciplinary research program. Our aim in this introduction is simply to outline some of the foundational issues and to speculate on ways in which these issues might be addressed in the future.

From brain to culture: some foundational issues

Two key issues which any new discipline faces concern its theory and method. On the issue of theory the principal challenges for neuroarchaeology, philosophical and epistemological, remain the same as those of cognitive archaeology in the broader sense. Although emphasis now falls naturally on the changing human brain and its long-term evolutionary and developmental trajectories, we should not forget that this is a brain inextricably tied with a body and firmly situated in culture and the material world. We believe neuroarchaeology should avoid falling into the trap of neurocentrism in which the brain is seen as the centre of the human world. To this end, a basic commitment to some, broadly defined, interactionist view of mind or maybe to some version of an 'extended' or 'distributed' mind hypothesis might protect us from sliding into neural determinism and thus from repeating the

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mistakes of the cognitivism of the 1960s — that is, mistaking the properties of the socio-cultural system for the properties of the individual. Over the last few decades we have learned a great deal about the social and cultural basis of the human mind, and the rapidly developing fields of comparative, developmental, social and affective neuroscience open new avenues for productive research cooperation between archaeology, anthropology and neuroscience. However, this leaves us with an important epistemological challenge of developing common relational ways of thinking about the complex interactions between brain-body-world. Our personal position in this context is firmly grounded on the theoretical framework of Material Engagement which we have been developing over recent years (Malafouris 2004; 2007; 2008; Renfrew 2004; 2006; 2007). The principal assumptions of this framework for the extended, distributed, enactive and mediated character of human cognition constitute also the theoretical basis upon which we aim to build the new field of neuroarchaeology. We recognize that these are contentious issues with which different researchers may well disagree. But behind these possible theoretical disagreements there seems to be a gradually emerging consensus about at least one major theoretical premise: when examining the interface between archaeology and neuroscience we need to expand the unit of analysis beyond the boundaries of the individual brain.

No less daunting a problem than its theoretical framework are the methods of neuroarchaeology. It is apparent that, among the tools of neuroscience, it is the functional MRI that has the greatest potential to play a prominent role in the context of cognitive archaeology. But how can these new imaging tools be best utilized from an archaeological perspective? Given the constraints imposed by using functional imaging how do we go about operationalizing an experiment to investigate specific patterns of archaeological evidence? How might archaeological experience inform the questions to be asked in the environment of the brain (MRI) scanner? Can there be a neuroscience of material culture?

If what neuroimaging can offer us is really nothing more than pretty pictures about where activity occurs in the brain, then we doubt that it can be of much help in our attempt to expand the analytic horizons of the archaeology of mind. Establishing testable, empirical links between brain structure, cognitive function and archaeologically observable behaviours is thus a central challenge in the development of a true neuroarchaeology. These exciting prospects, however, come with a clear requirement. Archaeologists must first understand neuroscience's methods, data and presuppositions before deciding which approach might best work. Therefore, it seems appropriate in the context of this introduction to consider some of the major assumptions and possible drawbacks behind brain imaging. We start with what we consider to be the most basic problem of all: 'To the man who has only a hammer, the whole world looks like a nail' (Kosslyn 1999, 1283). There can be no doubt that neuroimaging technologies opened a new window on the human mind but the phenomenological price for capturing the 'ghost in the machine' on paper is heavy. The static 'snapshot' view of brain activity that these activation data provide can very often be misleading. As Dietrich Stout reminds us 'PET images do not explain *how* neuronal activity contributes to mental behaviour' what they do indicate is *where* this activity takes place (2005, 280). As archaeologists we doubt that simply knowing where neural activity takes place is the sort of information that will in itself make the big difference in the study of human cognition. Naturally we are not questioning that neuroimaging provides us with a possible measure of what is going on *within* the brain during performance of a task, like knapping for example. What we suggest we should be cautious about is the extent to which measuring the increase or decrease in regional brain activity tells you, in itself, the most important part of the story about the cognitive task in question. We should bear in mind that one of the standard assumptions in neuroimaging is that there is a consistent mapping between cognitive function and neuroanatomy (Donaldson 2004). The usual kind of inference that can be found in most neuroimaging studies is of the form 'if cognitive process *X* is engaged, then brain area *Z* is active' (Poldrack 2006, 59). But although one may well expect a consistent correlation between the performance of a certain cognitive task and the bits of the brain that we see to light up, this correlation should not be confused with identity. In many cases structures activated in functional imaging studies fail to give rise to impairments when lesioned, indicating that particular tasks map onto relevant brain structures in a flexible and non-exclusive way (Edelman 1987).

Clearly there are many problems but also a great deal of promise, especially if one considers that brain imaging is itself in a very active state of constant development. Over the last few years especially, it has become increasingly clear that what a decade ago could be accused of being nothing more than a 'new phrenology' (Uttal 2001) is now rapidly changing, offering new tools and opening new research avenues for exploring the operations of the human

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brain. For instance, current research in practice-related neuroimaging — that is, neuroimaging studies concerned with the possible effects of practice on the functional architecture of the human brain — can now differentiate between patterns of 'redistribution' and 'reorganization' in the functional architecture of a certain task performance — e.g. the knapping task previously mentioned. In the former case, i.e. *redistribution*, the task activation map contains more or less the same brain regions at the end as at the beginning of practice but the activation level within those areas has changed (increase or decrease) as a result of practice. More simply, the functional anatomy of the task remains basically the same. In the case of *reorganization* however, a shift in the cognitive processes underlying a given task performance can be observed, which is reflected as a change in the actual location of activations. What this means is 'that neurobiologically and cognitively, different tasks are being performed at the beginning and end of practice' (Kelly & Garavan 2005, 1090; see also Poldrack 2000). We should note that Peterson *et al.* (1998) interpret the above as indicative of the existence of a *scaffolding* network of brain regions which are recruited to cope with the increased cognitive demands of unskilled performance at the early stages of practice, and which at a later stage fall away. The above findings clearly indicate that focusing on the changes in the neural context of activity, that is, the *interactivity* between different brain regions, is far more significant than focusing on changes in regional activity (e.g. McIntosh 1998, 556).

In other words, *time* and *context* are of the essence in human cognition whatever the scale you look at it. The crucial question for neuroarchaeology in this respect is 'what might be the appropriate "time window" that will enable us to move across the scales of time?'. How, for instance, can the different temporalities, of a brain activation map obtained during a given technical task and of a *chaîne opératoire* describing the same task, be integrated and complement each other? Despite the many problems that any attempt to cut across the scales of time has to confront, this is an objective which can now be partially accomplished by incorporating 'event-related' methods for examining the temporal profile of activity within each region of the brain (Donaldson 2004). In addition, new innovative methods are currently developed which enable the exploration of brain responses measured with fMRI during naturalistic tasks and the addressing of questions (e.g. about social interaction, memory or navigation abilities) that are either difficult or indeed impossible to ask using conventional passive viewing of static stimuli (see Spiers & Maguire 2007).

Future prospects

For many archaeologists perhaps, the questions and problems that surround the functional architecture of the human brain may not seem to be much of our problem. Cognitive archaeology should forget the brain and focus on the wider and archaeologically visible behavioural adaptations that made humans what they are. But accepting that adaptive behaviour, as Chiel & Beer suggest, is the result of the continuous interaction between the nervous system, the body and the environment, it follows that we can neither understand any component in isolation nor 'assign credit for adaptive behaviour to any one piece of this coupled system (Chiel & Beer 1997, 555). In order to account for the changes in human cognitive evolution, one should ask '[w]hat are the contributions of all components of the coupled system and their interactions to adaptive behaviour?' (Chiel & Beer 1997, 555). It is in the reconstruction of the neural correlates of this embodied and interactive system that neuroscience has most to offer archaeologists. Stone artefacts, for instance, provide some of the most detailed remaining evidence of pre-modern hominin behaviour and cognition, but without knowing what role the brain plays in the use and manufacture of a stone tool then how can we ever understand how a stone tool might have shaped the hominid mind? To give an example, recent brain-imaging studies of ESA tool-making show substantial overlap with neural systems involved in language processing (Stout & Chaminade 2007; Stout *et al.* 2008). These similarities coupled with the impressive plasticity of the brain make it quite plausible, as proposed by numerous hypotheses of tool-language co-evolution, that selection on non-linguistic behaviours may have been important in shaping language-relevant systems.

The same questions, of course, can easily be extended to other technological domains of skilled praxis such as navigating, hunting and food-gathering practices, as well as to other, less directly-observable processes (e.g. language, consciousness and self awareness). In addition, more recent developments, from the conscious use of symbols to the emergence of the first writing systems, raise their own challenges. It thus becomes necessary to explore a new kind of cognitive archaeology, recognizing that the differences in behaviour of humans born into a specific cultural context today and those, let's say, of 60,000 years ago are the product of successive and progressive life experiences of ongoing developmental plasticity and enculturation.

Considering the above issues, one might begin to provide a sketch of how the interaction between archaeology and neuroscience should proceed in the

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future in order to foster a two-way dialogue between the disciplines. As already mentioned, learning about the biological substrates of human cognitive becoming can help archaeologists and anthropologists to identify evolutionarily significant behaviours and better define archaeologically visible attributes. It is less clear, however, how neuroscience can benefit from archaeological knowledge. One obvious way that this can be accomplished is by using archaeological data to constrain models of human cognitive evolution. We suggest that there is also another less obvious way in which archaeology can influence neuroscience. That is, by showing how significant changes in human cognitive development are the product of engagement processes between humans and the material world realized in different trajectories of cultural development. It is now understood that the structure, the 'wiring' of the brain, is changed through the social experience of action, including speech and material engagement activities. New forms of engagement with the material world bring about new possibilities and constraints for the human brain. The development of new materials and technologies as well as of new uses of space and conceptions of time, as these can be observed in the archaeological record, can be our key to understanding how culture has been shaping the brain for thousand of years. New styles of objects would put novel demands on the bodies and brains of people making, using and appreciating those objects. Meanwhile, cross-cultural comparisons of their possible neural correlates may offer a bridge between neural and cultural plasticity. Thus neuroarchaeology could provide a new means for exploring the cognitive basis of cultural variation and difference.

The human mind is indeed to be understood as embodied, extended and distributed and as not restricted to the brain within the skull, yet the activity within that brain remains a crucial component of all cognitive processes. In the words of the philosopher Andy Clark: '[t]he real question, then, is not 'should we study the brain?' but 'how should we study the brain?' (1997, 130). As archaeologists we can hope to learn much about the remarkable plasticity of mind by exploring the neuroscientific basis for learning and for the development of material culture.

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