Special Section

Steps to a 'Neuroarchaeology' of Mind, part 2[1]

Hohlenstein-Stadel and the Evolution of Human Conceptual Thought

Thomas Wynn, Frederick Coolidge & Martha Bright

Cognitive neuroscience provides a powerful perspective on the brain and cognition from which archaeologists can begin to document the evolution of the human mind. The following essay uses the Hohlenstein-Stadel figurine as a starting point to demonstrate the two kinds of conclusion open to an evolutionary cognitive archaeology: first, describing features of the cognitive life-world at specific points in human evolution, in this case central Europe 32,000 years ago, and second identifying the evolutionary timing and contexts for specific cognitive abilities, in this case various components of concept formation. We argue that the abstract concept underpinning the Hohlenstein-Stadel figurine resulted initially from an effortful (attentive) linking of 'animal' and 'person' concepts via the working memory network of the frontal and parietal lobes. These 'animal' and 'person' concepts themselves were largely unconscious folk biological categories generated by a parietal network that had evolved earlier, probably by the time of the earliest Homo sapiens. *These in turn rest on even older, basic ontological categories of 'animate' and 'manipulable' objects that are temporal lobe networks, and which evolved much earlier still, perhaps with the advent of* Homo erectus.

The Hohlenstein-Stadel figurine is one of the most evocative of Palaeolithic objects. This 32,000 year-old Löwenmensch, or lion-man, has figured prominently in discussions of prehistoric religion and social life, and has even been used as an index of modern behaviour. Indeed, one could argue that it has acquired an iconic status for modern archaeologists as profound as it must have been for the original artisan. In the following essay and analysis we pursue the implications which the Hohlenstein-Stadel figurine presents for the evolution of human cognition, and in so doing hope to demonstrate the power of cognitive neuroscience as a theoretical foundation for evolutionary cognitive archaeology.

Hohlenstein-Stadel and contemporary early Upper Palaeolithic (EUP) artistic productions have already figured in cognitive archaeological discussions. Notable examples include Wynn's (1991) incorporation of Upper Palaeolithic depictions into an argument for the emergence of Piagetian formal operational intelligence, Noble & Davidson's (1996) use of depiction in their argument for language origins (with Hohlenstein-Stadel on the cover), and Mithen's (1996) discussion of the evolution of cognitive fluidity. All three were successful in providing new insights into the evolution of mind, largely because each was grounded in an established theory of cognition. But none became the foundation for vibrant growth in cognitive archaeology. The reasons are, perhaps ironically, also linked to their theoretical bases. Piagetian influence was on the wane by the 1980s, partly because its reliance on general stages of intelligence ran counter to much of the experimental evidence; ultimately it also failed to account for features of the archaeological record (Wynn 2002). The Gibsonian approach, which was an important component to Davidson's and Noble's argument, remains a viable but minor branch of perceptual psychology, but it

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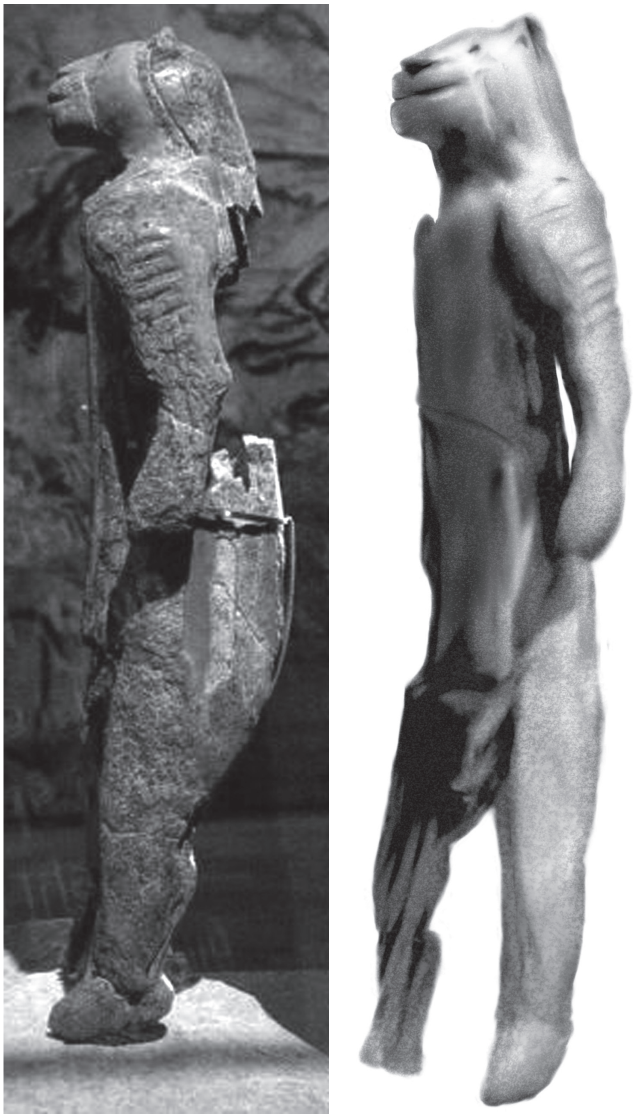

Figure 1. *Hohlenstein-Stadel Löwenmensch.*

has not been especially successful in broadening its explanatory power to other components of cognition. Mithen's theoretical foundation of developmental psychology had perhaps the most potential given the sheer scope of modern developmental psychology, but the ontogenetic/phylogenetic parallels on which it was based have continued to supply only very general insights. For evolutionary cognitive archaeology to grow as a mature approach, and achieve more than the very general conclusions reached to date, it needs more powerful theories. The one we advocate here is that of cognitive neuroscience.

Most simply put, cognitive neuroscience investigates the biological basis of cognition by combining the anatomical/physiological findings of brain science with the theoretical modelling power of cognitive psychology (Gazzaniga 2000). In the last fifteen years cognitive neuroscience has made considerable strides in identifying and describing neural networks that can be linked to specific cognitive abilities. The two pillars of the approach —neuroimaging and experimental psychology — make it especially amenable to the evidence and scientific leanings of cognitive archaeology. On the one hand, the emphasis on brain anatomy and physiology provides a potential link to the fossil record of human brain evolution via changes in the relative proportions of specific neural structures. On the other hand, experimental psychology provides sophisticated models of cognition that archaeologists can use to identify evolutionarily significant behaviours and define archaeologically visible attributes. From a grounding in cognitive neuroscience archaeologists should be able to address two kinds of questions: (1) interpretations of specific patterns of archaeological evidence in terms of the cognitive life-world of those who produced it, and (2) interpretations of the evolutionary timing and context of specific components of human cognition.

In the following article we set out to answer both of these questions. We will provide insight into the cognitive life-world of Aurignacian people who lived 30,000 years ago, and we will place the several neurocognitive components of human concept formation into their appropriate evolutionary contexts. We will focus on a single artefact, the Hohlenstein-Stadel figurine, but will also incorporate other selected components of the Palaeolithic record.

Hohlenstein-Stadel

The Hohlenstein-Stadel figurine is a carved ivory image of an upright standing human body with an intricately carved lion head (Fig. 1) (Hahn 1986).

It is 28 cm in height, is missing its right arm and foot, and little of the original surface of the figurine has been preserved. There are, however, a number of notches and visible markings, predominantly on the upper left arm and around the ears. The figurine was found tucked away in the very back of the cave, more than twenty metres from the entrance, and was spatially removed from the activity and living areas. Other non-utilitarian objects made of ivory, including ornaments and animal figurines, were found close by (Bradshaw 1997; Hahn 1986). The Hohlenstein-Stadel cave itself is located in the valley of the Lone River in Southwestern Germany, and was occupied from the Middle Palaeolithic through the Neolithic. The figurine was associated with the Aurignacian occupation, and has a relatively secure age of 30,000–32,000 years (Hahn 1986).

Ivory figurines appear to be restricted to the southern German Aurignacian, and this therianthrope's impressive face, details, size and apparent non-utilitarian function make it almost unique. Other Aurignacian figurines are known from nearby sites of Vogelherd and Geissenklösterle, and Conard (2003) has reported the discovery of three figurines carved from mammoth ivory at Hohle Fels Cave in the Swabian Jura of southwestern Germany. One of these is similar to the Hohlenstein-Stadel therianthrope, although less than one-tenth its height. Conard suggested that this second therianthrope lends support to the hypothesis that Aurignacian people may have practiced shamanism, and he argued it is strong evidence for fully symbolic communication and cultural modernity. These specific interpretations are not our present concern. Whatever its symbolic/social function may have been, this therianthrope has very interesting implications for human neurocognitive evolution.

Analysis

We aver that it is reasonable to conclude that the Hohlenstein-Stadel figurine was (and is) a material manifestation of an abstract concept. What, then, were the cognitive abilities and/or neural networks that underpinned such an abstract conception? The issue of concept formation is of course a long-standing psychological, philosophical, linguistic and even theological problem about which there is more than considerable disagreement, and which we will not pretend to resolve. However, cognitive science and cognitive anthropology have begun to trace the outlines of an account of concept formation that is powerful enough to incorporate Hohlenstein-Stadel, and thereby illuminate several of the steps in the evolution of the human mind.

It is the fossil record that motivates our focus on the role of conceptual thought and the parietal cortex in the production of the Hohlenstein-Stadel figurine. Bruner has recently (Bruner *et al.* 2003; Bruner 2004) made a strong argument for a non-allometric increase in parietal volume associated with the advent of anatomically modern humans (AMH). In a nutshell, the evolution of AMH out of *Homo heidelbergensis* was accompanied by an allometric increase in overall cranial capacity (so was the evolution of Neanderthals), but also a larger than expected increase in the parietal volume. An increase in parietal volume accompanied earlier developments in hominin evolution (Holloway 1995; Bradshaw 1997), but is especially marked in the advent of modern humans. Bruner concludes that '…modern humans show a species-specific neomorphic hyperthrophy of the parietal volumes, leading to a dorsal growth and ventral flexion (convolution) and consequent globularity of the whole structure' (Bruner 2004, 279). Bruner himself notes that the parietals, especially the posterior parietal cortex, are known to be important in visuospatial and sensory integration as well as multimodal processing and social communication (2004, 280, 299).

Unfortunately, the parietal cortex has been associated with a bewildering range of cognitive functions, including visuomotor control (grasping and reaching), attention, eye movement, motion processing, stereo vision, spatial and non-spatial working memory, mental imagery and mental rotation, response inhibition, task switching, alertness, calculation, and even pain processing and swallowing (Ashby *et al.* 1998; Culham & Kanwisher 2001; Faillenot *et al.* 1999; Hubbard *et al.* 2005; Saxe 2006; Shibata & Ioannides 2001; Thiel *et al.* 2004). More specifically, the inferior parietal cortex has been implicated in language deficits (Bradshaw 1997), the posterior parietal cortex with intention (Snyder *et al.* 1997), the lateral intraparietal area with decision making (Platt & Glimcher 1999), the temporoparietal junction with reasoning about mental states (Saxe 2006), and the medial parietal region and right parietal region with the representation of the mental and physical self, respectively (Lou *et al.* 2004). In fact, the stimuli and cognitive tasks that produce parietal activation show such a high degree of heterogeneity that some researchers suggest that a more appropriate question might be to ask what stimuli and tasks *do not* activate the parietal cortex (Culham & Kanwisher 2001). Not only are the behavioural associations complex, the neuroanatomy (Medin & Atran 2004; Atran 1990) itself is complex. Shibata & Ioannides (2001) have noted that the superior part of the posterior parietal cortex exhibits an extremely variable and asymmetrical surface area, and Castelli *et al.* (2006) add that human intraparietal neurons specifically are architectonically very complex. Almost every researcher investigating the parietal cortex and its functions stresses the extensive and widespread connections to many, indeed almost all, other parts of the brain (Martin & Carramaza 2003). Especially salient are connections to the prefrontal cortices (Ashby *et al.* 1998; Hodges *et al.* 2000; Jancke *et al.* 2001a; Lou *et al.* 2004; Saxe 2006; Thiel *et al.* 2004; Tranel *et al.* 2003).

This complexity is certainly daunting, but it strikes us that it is precisely this complexity that argues for the importance of the parietal cortex in the evolution of modern human cognition, particularly

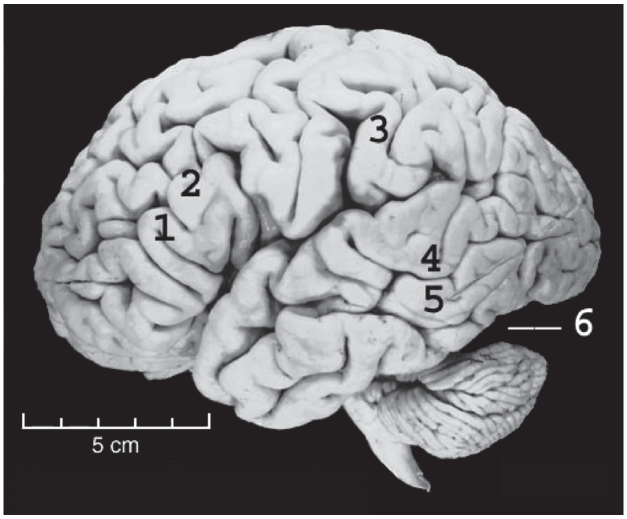

Figure 2. *General locations of regions discussed in text. 1) Ventrolateral prefrontal cortex (VLPFC); 2) Ventral premotor cortex (VPMC); 3) Intraparietal sulcus (IPS); 4) Posterior superior temporal sulcus (pSTS); 5) Posterior middle temporal gyrus (pMTG); 6) Fusiform gyrus (FG) (underside of temporal lobe).*

via its role in conceptual thought and in constructing mental models of the world. We tentatively suggest, based on data from archaeology, palaeoanthropology, and cognitive neuroscience, that modern humans deploy three varieties of conceptual thinking, that all three were used in conceiving the Hohlenstein-Stadel figurine, and that the three varieties emerged at different times in human evolution. The three are: basic ontological categories; taxonomies and multi-sensory models; and abstract concepts.

Basic ontological categories

Neuropsychology and brain-imaging research have demonstrated that all people come equipped with dedicated neural networks for perceiving and knowing about animate objects and manipulable objects (Martin 2007; Martin & Carramaza 2003; Mahon *et al.* 2007). These are primarily temporal lobe networks that have extensions to parietal and frontal cortices. They appear to be category based, but the information within each category appears to be represented as property based features. Not surprisingly, there is a partial overlap in the neural systems supporting perception and storage of these object properties. Both the ventral and lateral temporal cortices are involved in both perception and representation of these properties, with the ventral temporal handling properties of form, and the lateral temporal properties of motion (Martin 2007).

In the fusiform gyrus, a structure of the ventral temporal lobe, information about the form of manipulable objects is processed medially, while information about the form of animate objects is processed laterally. The involvement of the fusiform gyrus is independent of the format of the information (visual, auditory, or lexical), supporting the hypothesis that the representations are organized by category. The circuitry for manipulable objects has extension to the posterior middle temporal gyrus (pMTG), which supplies motion properties. The 'animate object' circuit has extensions to the posterior superior temporal sulcus (pSTS), which also supplies motion properties. These circuits are involved in recognition of animate and manipulable objects, and in constructing images. Higher order processing of concepts occurs in parietal lobes (intraparietal sulcus; IPS) and the ventral premotor cortex (vPMC) (Fig. 2). It is especially interesting that higher order object concepts engage both the form and movement representation circuits of the temporal cortex, and the premotor cortex that governs motor use of the object. It suggests that tool concepts include very real motor representations, in addition to any image content.

Evidence from developmental psychology suggests that these base level categories of phenomena are in fact largely innate. Infants appear able to form the categories of animate and inanimate by the age of three months (documented via an experimental protocol in which infants show surprise or fixate on unexpected phenomena, such as inanimate objects moving of their own accord). They show a special interest in animate objects, and soon build a concept of 'animal' by clustering disparate perceptual features, including the notions of '…things that start by themselves, move in rhythmic although not always predictable way and interact with other objects contingently, both directly and from a distance' (Mandler 2004, 504). Pre-verbal children are capable of such concept formation, and Mandler suggests that the ability is rooted in an innate attentional bias toward paths of motion, which, as we have seen, are processed largely by the posterior temporal cortex.

The basic distinction between animate and manipulable objects is pre-attentive (though it is also involved in conscious imagery). Our brains come pre-programmed to recognize these categories. To palaeoanthropologists one of these categories — manipulable objects — is provocative. It suggests that features of human neural circuitry may have evolved to perceive (recognize) and represent tools. Of course, the palaeoanthropologists would also like to know just what the brain includes within this category (does it include rocks, for example?), but neuroscientists have not yet defined the ontological boundaries. There is some experimental evidence (via a stimulus repetition suppression protocol) that the left medial fusiform may be especially sensitive to tools *per se* (Mahon *et al.* 2007). Such a 'tool' circuit implies the existence of tools as an ontological category, and it is not until the advent of Mode 2 technology, with its handaxes and cleavers, that archaeologists have any reason to suspect that a category of 'tool' existed in the heads of our ancestors. The bifaces of Mode 2 technology also indicate an attention to the form of the artefact, and such shape recognition has long been associated with the 'ventral processing stream' of the temporal lobes (Wynn 2002). Mode 2 technology emerged a very long time ago (ca. 1.5 million years), which suggests that the modern human neurocognitive distinction between animate and inanimate objects, which certainly played a role in the Hohlenstein-Stadel figurine, may stretch back to the advent of *Homo ergaster/erectus.*

Taxonomies and multi-sensory models

The basic ontological categories of 'animate' and 'manipulable object' may be among the necessary base-level models of the hominin natural world, but they are insufficient to generate an idea such as the one underpinning the Hohlenstein-Stadel figurine. Clearly, 'lion' is more specific than animate being, and the notion of 'person,' as opposed to 'self' or 'other', would appear to be needed as well. It is here that we must turn to the murky world of concept formation. Much relevant research has come out of experimental psychology, neuropsychology and neuroimaging, but perhaps the most provocative conclusions about human concept formation have been revealed by the cross-cultural research of cognitive anthropologists.

Not only do people deploy the ontological category of 'animate', whose properties consist of perceptual features, they also sub-divide this animate world in a very specific way. By studying how people in different cultures solve problems and think about their world, cognitive anthropologists have identified a number of universal patterns of thought. Wherever people live, they think about certain phenomena in identical ways. Because these ways of thinking are universal they must have a neural basis, in much the same way that the language faculty has a neural basis. Cognitive anthropologists have labelled these universal patterns of thought 'folk mechanics' (a.k.a. folk physics), 'folk psychology', and 'folk biology.' It is the latter that is perhaps the best documented, through the work of Atran and colleagues (Medin & Atran 2004; Atran 1990), and also the most relevant to understanding Hohlenstein-Stadel.

> In every human society, it appears, people tend to think about plants and animals in the same special ways. These special ways of thinking, which can be described as *folk biology*, are basically different from the ways humans ordinarily think about other things in the world, such as stones, tools, or even people. (Medin & Atran 2004, 961–2)

Folk biological concepts are structured by two organizing principles. The first is ranking. Everywhere, people divide the natural world into ranked taxonomies, with the taxa at each rank being mutually exclusive. The minimum number of ranks is three, but there can be as many as six. This ranking principle is not just an abstract principle of hierarchical inclusion because the 'contents' of each rank level are also universal. If a culture recognizes (and labels) three ranks, these ranks will be folk 'kingdom' (e.g. plant), folk 'life form' (e.g. tree), and folk 'generic/specific' (e.g. oak). Such a ranked taxonomy is not inherent in the natural world, where more continuous variability is the norm, and such categories as 'tree' have no reality. The second organizing principle of folk biology is essentialism. People do not define a taxon as a polythetic type, or a statistical average. Instead, they believe each taxon has an underlying causal nature or internal essence. Oaks are defined by oakness, trees by treeness, and so on. Even if an individual cannot specify what constitutes 'oakness,' he or she will be committed to the idea that there is such an essence to the taxon (Medin & Atran 2004, 962).

Medin & Atran do not identify particular neural substrates for these two principles of folk biology. They favour a solution in which folk biology is a functionally autonomous domain or network in which information is privileged but not proprietary. We suggest that these domains heavily involve the parietal cortex. First, the 'essence' of any folk biological taxon is almost certainly a multi-sensory model of some sort and second, ranked taxonomies have a definite spatial flavour to them. Both multi-sensory and spatial models are primarily parietal lobe functions. A number of researchers elaborate on the central role that the parietal cortex plays in integrating visuospatial information and multi-modal processing (Faillenot *et al.* 1999; Jancke *et al.* 2001b). For example, Grefkes & Fink (2005) note that the areas around the intraparietal sulcus (IPS) have been shown to integrate neural signals from different sensory modalities for guiding and controlling action in space through furnishing the actor with three-dimensional surface and mental representations of the objects surrounding him or her (and recall that Martin [2007] identifies the IPS as being involved in higher order object concepts). These sensory modalities are comprised of visual, auditory, and somatosensory information (Bradshaw 1997; Culham & Kanwisher 2001; Holloway 1995; Tranel *et al.* 2003). Thus, human parietal cortex enables one to 'maintain the map of extracorporeal space wherein behaviour is elaborated, responses are initiated, and exploration directed' (Bradshaw 1997, 137). These integrative processes of the parietal cortex are closely linked to the capacity to function adaptively within one's natural and social environment. One of the ways in which modern humans function adaptively is through folk biology, and the parietal cortex is almost certainly the locus in the brain where the raw data for such concept formation converges. The neural networks supporting folk biology are unlikely to be exclusively parietal, but they are likely to be heavily involved in constructing the folk biological model of the world. It is impossible at this point to be more specific than this. Nevertheless, the role of parietal cortex in concept formation is strongly enough established for Bruner to invoke it as the likely neural function that led to the non-allometric expansion of the human parietal cortex that accompanied the evolution of anatomical modern humans (Bruner 2004; Bruner *et al.* 2003).

Archaeological support for Bruner's hypothesis is paradoxically thin. In principle, more complex concepts and mental models of the world could have consequences in material culture. Unfortunately, the archaeology of early anatomically modern humans is notoriously archaic in appearance, especially in the domains of technology and subsistence. This deficit may, however, be at least a bit deceptive. Technology and subsistence are domains of action that rely heavily on well-learned procedural routines, and not on complex mental models. However, there are hints that more complex mental models may in fact have been a feature of early AMH thinking. One hint comes from the Herto skulls, which had apparently been carried around in bags after being defleshed. Though we obviously do not know why the Herto people did this, it does suggest some kind of social marking, either of the dead or the living, and such marking implies a person concept that is considerably more elaborate than those of self, mate, child, and other. A more convincing example, though later in time, is that of the Blombos beads (d'Errico *et al.* 2005). The only reason to produce personal ornaments is to mark identity in some way. The presence of beads at Blombos suggests that these people needed to mark identity. Robin Dunbar (Dunbar *et al.* 2005) has argued that when social networks expand beyond the 150 individuals that one can maintain using face-to-face interaction that it is necessary to deal with some people as categories. Such categories are easiest to engage if they are marked. So the presence of beads suggests that the Blombos social world reached beyond the local band to include other identified groups. These could not have been just 'strangers', who could be dealt with easily as unknown others. They must have had differing social roles to play: those to whom we give spouses; those from whom we get spouses; those with whom we trade; enemies; and so forth. Conceiving of such a social world required a set of social concepts that were considerably more elaborate than those we need posit for archaic humans such as Neanderthals, whose social reach almost certainly did not extend beyond the magic 150 (Gamble 1999; Wynn & Coolidge 2004). We must aver strongly at this point that our interpretation of the Blombos beads does not require that these people had a modern syntactical language, though lexical marking of the categories would seem a reasonable conclusion. These archaeological traces are not smoking guns for concept formation. The ever elusive example of depictive art would be such a smoking gun, because depiction would require the kind of a multi-modal concept associated with parietal lobe function (this conclusion is similar, in some senses, to that of Davidson and Noble concerning concept formation: Davidson & Noble 1989; 1993, though the theoretical justification is very different). We would not be surprised if depictive images were eventually discovered in association with early AMHs; indeed, this is a prediction of our hypothesis. Such a concept would be required for a depictive figurine like Hohlenstein-Stadel, but it would still not be quite enough.

Abstract thinking and executive functions

The concepts and categories generated and integrated via the temporal-parietal network are the product of a largely unreflective, effortless, integration of information. We do not structure the natural world taxonomically via sustained attention; it just comes to us. In a sense, we did not invent it; it evolved. Bruner's parietal expansion may well reflect an evolution in the complexity or number of such pre-attentive models, although there is as yet little archaeological evidence for this. But what it did not entail was the ability to imagine superordinate, overarching categories that merged pre-attentive conceptual domains, or to imagine abstract entities. The artisan who imagined Hohlenstein-Stadel must have accessed two distinct concepts (person and lion), generated by two largely distinct neural networks. He or she then must have held them in active attention and merged them. This kind of effortful merging is the province of working memory.

We have already proposed that the additive genetic neural mutation may have affected non-domain specific working memory (WM) capacity or one of its subsystems (Coolidge & Wynn 2001; 2004; 2005; Wynn & Coolidge 2003; 2004). WM is a theoretical construct initially proposed in 1974 by Baddeley & Hitch (Baddeley & Hitch 1974) reflecting a capacity to hold and manipulate information in active attention consistent with short- and long-term goals, in spite of task-irrelevant interference. As currently conceived (Baddeley & Logie 1999; Baddeley 2001; 2007), WM is a multi-component cognitive system consisting of a central executive and two subsystems, (a) phonological storage with vocal and subvocal articulation, and (b) a visuospatial sketchpad. Baddeley also proposed an episodic buffer that integrates information from the two subsystems and serves as a temporary store for this information and other material at the behest of the central executive. Three components of WM, the central executive, phonological storage, and visuospatial sketchpad, have received strong empirical support (Miyake & Shah 1999; Baddeley 2007). The chief function of the central executive is the maintenance of task relevant material consonant with goals in spite of interference. We have previously suggested that these central executive functions, including decision making, complex and novel problem solving, action selection, maintenance of attention in spite of distractions, planning, and response inhibition, have heretofore been known as executive functions of the frontal lobes, and thus, have nearly five decades of empirical support (e.g. Coolidge & Wynn 2005).

WM's phonological storage subsystem serves as a short term store for acoustic stimuli (primarily words), and it includes a vocal and subvocal articulatory processor, which serves as a rehearsal mechanism for maintaining sounds or words in active attention. The visuospatial sketchpad temporarily maintains visual ('what') and spatial ('where') information such that appropriate verbal identification tags may be attached to the stimuli by means of the episodic buffer, and subsequently stored in long-term declarative or procedural (in the case of a skill such as stone knapping) memory (see Baddeley 2007, or Miyake & Shah 1999 for additional information about WM and its components).

Our hypothesis is that an additive genetic mutation occurred specific to working memory capacity. It has been repeatedly shown that WM's various components have a highly heritable basis. Core functions of the central executive (e.g. planning, organizing and goal attainment) were found to be exceptionally heritable (77 per cent) and attributable to a polygenic influence (Coolidge *et al.* 2001). The phonological storage component of working memory has also been shown to be strongly heritable, e.g. 35 per cent to 56 per cent, and polygenic (Ando *et al.* 2002; Rijsdijk *et al.* 2002). Ando *et al.* found their measures of the central executive and visuospatial sketchpad were also strongly heritable (37 per cent to 57 per cent). Hansell *et al.* (2001) demonstrated that the visuospatial sketchpad had a similar polygenic heritability (35 per cent to 52 per cent).

Neuropsychological and brain imaging research indicates that WM is largely a frontal lobe neural network, with significant links to parietal and temporal lobes. The dorsolateral prefrontal circuit is generally associated with the classic executive functions mentioned previously. The orbitofrontal prefrontal region is more closely connected to the limbic system and been shown to be associated with the processing of emotions and the regulation of social behaviour and social interactions. Both systems are closely connected, and the prefrontal cortex in general has extensive projections to almost all regions of the temporal, parietal, and occipital lobes, and to subcortical structures such as the basal ganglia, the cerebellum and many brainstem nuclei. The gist of these interrelationships appears to be that the prefrontal cortex coordinates the processing of broad regions of the central nervous system. A third region of the prefrontal cortex is the anterior cingulate gyrus, and it is thought to mediate motivational systems and action selection (Pennington 2002). These findings are also important to Hodgson and Helvenston's (2006) hypothesis that the frontal lobes, in particular area 10 of the prefrontal cortex, and their connections to other lobes, were critical to the ability of modern humans to represent the animals and therianthropes of Upper Palaeolithic art.

Conclusion

At the outset of this article we identified two goals for any evolutionary cognitive archaeological analysis — understanding a specific pattern from the past and placing specific cognitive developments in their appropriate evolutionary context. How, then, has our analysis of the Hohlenstein-Stadel figurine fared?

1. Our analysis confirms the generally held opinion that Aurignacian people were behaviourally modern. Though this therianthrope does not embody all components of modern behaviour, the pattern

of conceptual thought it does preserve is modern in all respects:

- The individual who conceived and executed the figurine was clearly capable of abstract thinking. A *Löwenmensch*, or lion-man, is not a creature of this earth. It melds the cognitively distinct categories of lion and person into a single, abstract entity, endowed no doubt with many features we cannot see. This melding must initially have been the result of an effortful conjunction of information in active attention, and such effortful conjunction is the province of modern executive functions and working memory. It relies on a complex neural network centred on the dorsolateral prefrontal cortex with extensions into the parietal and temporal cortices. This kind of effortful musing is a familiar feature of modern thinking. It is this cognitive feature of the figurine that is probably most salient for the proposed symbolic functions of the artefact (e.g. shamanism [Conard & Bolus 2003]). But it rests ultimately on another, largely pre-attentive cognitive categorizing ability.
- The essence-defined, taxonomic distinctions of modern folk biology are also in evidence. 'Lion' is a member of a sub-division of 'animal', defined almost certainly by the essences of 'lioness.' Such a folk biology is universal for modern humans, so in this sense at least Aurignacian thinking is very familiar. The neural basis of folk biology is harder to specify than that of abstract thinking, but it would appear to rely heavily on parietal lobe networks. The parietal cortex is responsible for our multi-sensory models of the world. The essence of a category is likely to be such a multi-sensory model, and a structure of ranked taxonomies almost certainly taps into the spatial modeling abilities of parietal cortex. These multi-sensory models in turn build upon an even more basic cognitive category distinction.
- At this more basic level is the human brain's ability to distinguish between animate and manipulable objects. In order to have a category of lion, it is first necessary to have a category of animate object, and to have a figurine it is first necessary to have a category of manipulable object. This categorical distinction emerges very early in ontogeny, perhaps as early as three months, and is based on perceptual biases in the visual system itself; i.e., it is largely innate. These base level object concepts are processed initially in the temporal cortex.
- There is a fourth cognitive network that is also necessary, although because it does not rest on conceptual thinking *per se* we have not discussed it. This is the domain of technical thinking. It relies heavily on procedural knowledge and memory, a network largely distinct from those discussed here (Wynn & Coolidge 2004).

In sum, if the Hohlenstein-Stadel figurine is a reliable indicator of the abilities of Aurignacian people generally, then they relied on conceptual thinking that is indistinguishable from that of people in the modern world.

2. The analysis also has implications for the evolution of these neural systems. Holloway (Holloway *et al.* 2004) has argued that hominin brain evolution occurred as a mosaic. The evolutionary cognitive archaeology of Hohlenstein-Stadel clearly suggests that human concept formation, in particular, evolved as a mosaic.
   - The base category distinction between animate and manipulable objects is old (by human standards, at least). The most likely timing for this development, based on known features of the Lower Palaeolithic archaeological record, was sometime in the early evolution of *Homo erectus/ergaster*. The development of bifaces as true tools, made with attention to shape, carried from place to place in anticipation of need, and likely produced by everyone, suggests that a tool category was in place. Possible palaeoneurological corroboration comes from an increase in brain size in which maximum width is located at the temporal base (Bruner 2003).
   - The evolution of multi-sensory folk biological models appears to have occurred much later in time, perhaps not until the advent of *Homo sapiens*. Here the most compelling evidence is primarily palaeoneurological via the marked non-allometric expansion of the parietal cortex (Bruner 2004; Bruner *et al.* 2003). But there are also some hints from the archaeological record, especially the evidence for the development of social marking in the guise of beads, or perhaps even human skulls. A cognitive repertoire of folk-biological categories might well include the production of images of concrete folk-biological entities. It would not surprise us if images of animals were to be found in earlier contexts than they have to date; indeed that is a prediction of this analysis.
   - Abstract concepts and executive functions appeared only very late on the evolutionary scene. Here there are no obvious developments in

gross brain anatomy on which to rely. But several different lines of archaeological evidence — technology, foraging systems, algorithmic devices, and social networks — all yield the same very late signature for executive functions, which are the behavioural manifestation of enhanced working memory (Coolidge & Wynn 2001; 2005; Wynn & Coolidge 2003; 2004). Indeed, Hohlenstein-stadel is arguably the oldest convincing evidence for modern executive functions yet identified. Because we have based our analysis within the context of a well-developed theory of the brain and cognition, we have opened the door to falsification. Indeed, our conclusions could be falsified through experimental results or through new discoveries in palaeoanthropology. If research in cognitive neuroscience demonstrates that folk-biological categories are not heavily dependent on networks of the parietal cortex, then this piece of our hypothesis would be falsified. If archaeologists discover remains of depictions of abstract concepts that are as old as the first anatomically modern humans, then our interpretation of the timing of the evolution of modern cognition would no longer be tenable.

Thomas Wynn
Departments of Anthropology
University of Colorado
1420 Austin Bluffs Pkwy
Colorado Springs, CO 80933-7150
USA
Email: twynn@uccs.edu

Frederick Coolidge
Department of Psychology
University of Colorado
1420 Austin Bluffs Pkwy
Colorado Springs, CO 80933-7150
USA
Email: fcoolidg@uccs.edu

Martha Bright
Department or Anthropology
University of Colorado
1420 Austin Bluffs Pkwy
Colorado Springs, CO 80933-7150
USA
Email: martha.bright@hotmail.com

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Author biographies

Thomas Wynn is Professor of Anthropology at the University of Colorado at Colorado Springs. For over thirty years he has advocated for the use of formal psychological theories in interpretations of the Palaeolithic record. His particular interests have been the evolution of spatial cognition and working memory.

Frederick L. Coolidge is a Professor of Psychology at the University of Colorado at Colorado Springs. One of his research interests is the application of cognitive and psychological theories to the archaeological record.

Martha Bright completed her undergraduate Anthropology studies at the University of Colorado at Colorado Springs in 2007. She is currently employed by Alpine Archaeological Consultants, Inc. conducting CRM work primarily in Colorado, Utah and Wyoming. Her main field of archaeological interest is the European Upper Palaeolithic with a special focus on depictive art and its cognitive underpinnings.