



Trees and ladders: A critique of the theory of human cognitive and behavioural evolution in Palaeolithic archaeology

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ABSTRACT

The modern biological model of (human) evolution is that of a branching tree. By contrast, prevailing models for human cognitive evolution remain unilinear in character, representing a ladder. The linear ladder model is the result of the opposition of an ethnographic and a primate reference frame for cognition, representing the two ends of what by definition becomes a linear line of evolution. It forces all types of behaviour that are not considered fully “modern” to assume a position at a lower level of cognition. The linear model is in addition pushed by the (flawed) perception of a linear encephalization trend over time. The structure of this linear model is not fundamentally based in either modern evolutionary theory or the archaeological record. The model itself is even structurally immune to constraints from pertinent data. Adopting a branching tree model instead has serious implications for views on hominin cognition and particularly the meaning of being “behaviourally modern”. In a branching model, “modern behaviour” no longer has a unique status as being *by necessity* the most sophisticated level of cognition, turning many of the traditional implications derived from the possession of “modern behaviour” moot. The challenge that adoption of a branching tree model creates is that ways have to be devised to account for unique cognitive expressions that are not covered by the existing framework of ethnography and primatology. In addition, notions about the “superiority” of “modern behaviour” over other forms of cognitive expression have to be abandoned. The advantage is that the model is structured to pertinent archaeological data and actually testable with archaeological data. Two case studies from the Lower and Middle Palaeolithic of Europe probe the construction of unique models for mobility strategies “bottom up” from archaeological data, providing a unique alternative to mobility models and their cognitive implications as derived from “bottom down” application of an ethno-primatological framework.

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1. Introduction

The time that human evolution was thought to have progressed from primate ancestor to us through a series of linearly linked archaic stages, lies several decades behind us. In the modern study of human origins, a branching tree model has become the standard representation of our phylogenetic evolution (Tattersall, 1995:232–234, 2009:110–111; Wood, 1996, 1992a,b; Delisle, 2001; Lewin and Foley, 2004). It is well accepted that a number of hominin species lived contemporary to each other. For example, *Homo ergaster* and late robust species of *Australopithecus/Paranthropus* in Africa between 1.8 and 1.5 Ma, with *Homo georgicus* living in Eurasia around the same

time; and *Homo neanderthalensis* in Europe, early *Homo sapiens* in Africa and late *Homo erectus* and possibly *Homo floresiensis* in Asia between 150 and 30 ka. While the exact phylogenetic relationships between the different hominin species that make up the phylogenetic tree is debated (Fig. 1 gives one of several competing models as an illustration to the general model. For another version, see for example Wood (1996:947)), the branching tree model as such is widely accepted, certainly now cladistics has become the mainstream way of creating phylogenies (Delisle, 2001:119).

When it comes to models of cognitive and behavioural evolution, the matter is different. Most scholars remain implicit in what model (linear or branching) they use, but their narrative typically implies a linear approach, as explicitly recognized by Foley (1988:207–208) and Tattersall (2009:111); and see for example Mithen (1996:211, Fig. 33). This unilinear model expresses the evolution of cognition and associated behaviour as a progressive

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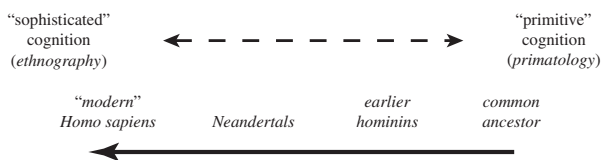


Fig. 1. Phylogenetic tree of human evolution.

single line from primitive primate ancestor to sophisticated “behaviourally modern” *H. sapiens* (Fig. 2a).

This conceptual unilinear model of the evolution of cognition in Palaeolithic archaeology and palaeoanthropology is remarkably at odds with the branching tree model of phylogenetic evolution. This paper highlights the reasons why unilinear thinking prevails with regard the evolution of cognition, and the implications of changing to a unified branching tree model for both phylogenetic and cognitive evolution.

a linear model



b branching tree model

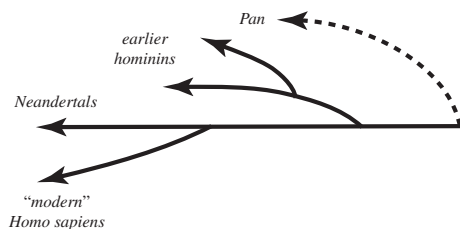


Fig. 2. The linear model (a) and a branching tree model (b) of cognitive evolution.

2. Linear models of cognitive evolution in Palaeolithic archaeology

At least three elements of reason and methodology are behind the persistence of an implicitly unilinear model of hominin cognitive evolution.

2.1. Ethno-primatological referential framework

One comes from the behavioural framework palaeoanthropologists employ to contextualize and explore the archaeological evidence. The framework is referential (Tooby and DeVore, 1987). Behavioural models gleaned from ethnographic studies of modern hunter-gatherer societies provide the yardstick for the “sophisticated”, complex end of the linear cognitive model. Primate ethological studies provide the “primitive” or “ancestral” end, either by using extant apes as a direct analogue, or by looking for shared traits between extant apes and modern humans (e.g. Byrne, 2001). These two reference frames are put in opposition, representing the two ends of what *by definition* becomes a linear line (Fig. 2a). This has been most explicitly stated and recognized in the context of the revision debates on the role of primatological and ethnographic models in human evolution that took place in the late 1980s and 1990s (e.g. Tooby and DeVore, 1987; Foley, 1988; McGrew, 1992):

“Many researchers view human evolution as a long corridor, where chimpanzees enter at one end and modern hunter-gatherers exit at the other” (Tooby and DeVore, 1987:203)

Two decades later, not much has changed:

“minimalist and progressivist interpretations of hominid history still tend to dominate our science, underpinned by a widespread perception that, for the past 2 million years at least, hominid history has largely been a story of not much more than increasing brain size and behavioural complexity” (Tattersall, 2009:111).

Archaic hominin behaviour is typically assumed to fall somewhere on a line between two ends of the spectrum: primitive “ape”-like hominin, and modern hunter-gatherer. The resulting model can be described as a linear “ladder” with different hominin species on different steps on this ladder, representing different stages in cognitive development.

2.2. Linearity, brains and cognition: it is not just size that matters

The linear approach to cognitive evolution is strongly reinforced by a second element: the conceptual link to a perceived “trend” in brain size over time starting 2 Ma ago (as per the Tattersall quote above). Trends are implicitly forcing linear views, especially when illustrated in diagrams of brain size versus time, illustrations that can be found in many synthesis of hominin evolution (Fig. 3a gives a generic version). These diagrams express hominin evolution as a linear encephalization process. Tellingly, the top and bottom referral lines of this kind of diagram are often the brain volumes of extant apes, and modern *H. sapiens*.

Specific ties can be expected between the evolution of the brain and the evolution of cognition (Dunbar, 1998; Byrne and Bates, 2007). An important point is that different evolutionary trajectories can result in similar brain volumes but different brain organization (Bruner et al., 2003; Schenker et al., 2005). Considering cognition, brain structure or organization (e.g. Dunbar, 2007:102; Bruner, 2010; Bruner and Holloway, 2010) and the influence of post-natal ontogenesis of the brain on brain structure is as important as size. The evolution of brain structure can be expected to be

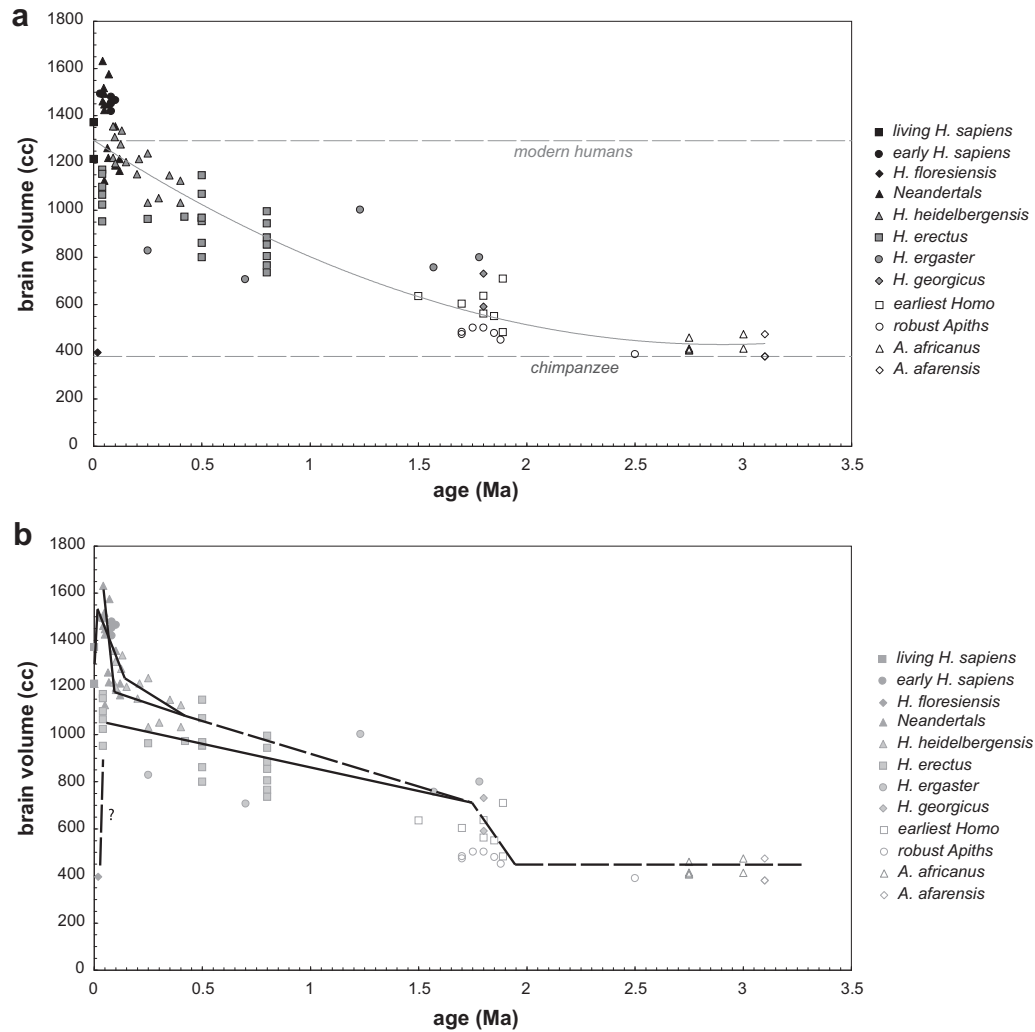


Fig. 3. a. Generic diagram of hominin brain evolution such as can be found in many textbooks. Diagram made by the author, with brain volume data from Aiello and Dunbar (1993); Gabunia et al. (2000); Falk et al. (2005); Lordkipanidze et al. (2006); and some minor revisions in the associated fossil ages. Note the outlier character of *H. floresiensis* and to a lesser extend latest *H. erectus* on the small side of the spectrum; and Neandertals and Pleistocene *H. sapiens* on the large side of the spectrum with regard to the “trend” (which is a 2nd order polynomial fit to the data). b. Same diagram as 3a, but adapted to reflect a likely branching nature of brain evolution, following phylogenetic lines.

closely tied to phylogeny structure, and hence follow a branching tree model of evolution (e.g. Bruner et al., 2003; and see Fig. 3b for a graphic representation of the concept).

This has been demonstrated for extant apes by Schenker et al. (2005). Using MRI scans of human and primate brains, they demonstrated structural differences in the ratio of cortex to gyral white matter between different hominoid species that they argue, “suggest that evolutionary forces can also act on individual circuits within the brain without having to act on all, and that such changes can take place independently of overall brain size” (Schenker et al., 2005: 561). Bruner et al. (2003) argued from fossil endocranial morphology that the similar sized brains of Neandertals and (early) *H. sapiens* are the result of two distinct evolutionary trajectories of the brain.

Differences in post-natal ontogeny of the brain, even if similar final brain volumes at adult age are concerned, likewise can translate to differences in cognition. Within *H. sapiens*, deviations in early childhood brain growth rate (Redcay and Courchesne, 2005; Courchesne et al., 2007) and/or the synaptic pruning process that starts at an age of about 12 months and goes on until late adolescence/early adulthood depending on which part of the brain it concerns, have been implicated to be behind autistic spectrum

disorders, schizophrenia and giftedness (Gogate et al., 2001; Redcay and Courchesne, 2005; Shaw et al., 2006; Hazlett et al., 2006; Courchesne et al., 2007; Gogtay and Thompson, 2010). Childhood Onset Schizophrenia (COS) for example, is characterized by a (relative to “healthy” children) accelerated pruning of cortical Gray Matter (GM) starting at age 9: while a relative gain of GM in the left temporal cortex and a relative loss of GM in the right temporal cortex is coupled to Bipolar I disorder (Gogate et al., 2001; Gogtay and Thompson, 2010). Individuals with autism spectrum disorders generally show an increased amount of GM in the left brain hemisphere, notably in the frontal and temporal lobes (Hazlett et al., 2006). Children with exceptionally high intelligence show a rapidly accelerated and prolonged growth of their cortex, followed by a vigorous thinning in early adolescence (Shaw et al., 2006).

The afflictions discussed above with their deviating pattern of post-natal brain ontogeny are all ‘disorders’ of cognition, and giftedness is deliberately included here to show that the effect is not always ‘negative’ (i.e. resulting in cognitive deficiencies) but can be ‘positive’ as well. If structural differences in these ontogenetic aspects of the brain existed between different hominin species such

as *H. sapiens* and Neandertals (and they might; see Gunz et al., 2010) or even within hominin species (e.g. early anatomically modern *H. sapiens* and current *H. sapiens*), this might have implications for aspects of their cognition, notwithstanding similar final brain volumes. Incidentally, if one is looking for causes behind the emergence of “modern behaviour” in *H. sapiens* during the Late Pleistocene, evolutionary changes in the post-natal ontogenetic maturation processes of the brain are good candidates.

Currently, there is very little insight in these aspects of hominin brain ontogeny, although recently Gunz et al. (2010) presented some tantalizing evidence suggesting there indeed were differences in post-natal brain development between modern *H. sapiens* and Neandertals. Any cognitive differences resulting from these ontogenetic differences should express themselves behaviourally (as they do in for example the *Pan* species *trogodytes* and *paniscus* (Wobber et al., 2010)), and hence be visible archaeologically. Current research methods and models of cognitive evolution are, however, not well fit to probe these issues.

2.3. Piagetian models

A third instance of linearity inherent in a model is the use of Piagetian models of cognitive development in lithic studies (Wynn, 1979, 1981, 1985). Piagetian theory is founded in developmental psychology, describing the process of human cognitive development from infancy through childhood and adolescence to adulthood. It is by definition a theory that describes the development of cognition as progressing through a series of stages of increasing complexity. Effectively, this forces a linear view when used to characterize the evolution of cognition in hominins over time. Piagetian theory has come under attack in developmental psychology itself (for a discussion, see e.g. Sutherland, 1992), notably because a number of studies implied that patterns in cognitive development are domain-specific, not generalized over different domains.

3. Summing up the problem: a mismatch of evolutionary models

The overview above serves to outline the central problem and core issue of this paper: existing reference frames for the evolution of cognition force unilinear, ladder-like views, while modern biological models of phylogenetic evolution (including that of hominins: which should include the evolution of their brains) are distinctly non-linear. Hence, a structural mismatch between biological models of hominin evolution and models of cognitive evolution can be observed.

It is important to observe as well that the discussed linear models for cognitive evolution are not well-rooted in archaeological evidence. This is unlike current phylogenetic models of hominin evolution, which have a strong foundation in the fossil record. What is even worse: current models for cognitive evolution are largely immune to testing against the archaeological record (again unlike phylogenetic models, which are constantly tested against the fossil record). Even though archaeological data and physical-anthropological data are channelled into these linear models of cognitive evolution and interpreted by them, the *structure* of the models used itself is not based on the structure of the fossil or archaeological record, and not put to discussion.

From a modern evolutionary perspective, these unilinear models for the cognitive evolution of hominins are fundamentally flawed. They need to be replaced with models more closely in sync with the branching tree model of modern evolutionary biology.

Before continuing and in order to avoid misunderstandings, it must be clear that the critique on the use of an ethnographic-

primatological framework for understanding cognitive evolution is *not* a critique on the use of Middle Range Research methods in archaeology. The seminal work on developing Middle Range Theory (with a strong ethno-archaeological component to its methodology) by Binford and others during the 1970s and 1980s has been tremendously important in understanding both the character and ambiguity of the relationships between dynamic process (hominin activities) and the resulting static outcome (the archaeological record). This is knowledge that is of vital importance in order to tackle the issues raised in the current paper, specifically the effort to discern unique behaviours in the archaeological record discussed near the end.

The reader will moreover note that the case studies later in this paper *do* incorporate a discussion of the similarities and dissimilarities of behaviour of Lower and Middle Palaeolithic European hominins with regard to both ethnographic observations on *H. sapiens* as well as ethological observations on chimpanzees. The critique on the use of ethnographic and primatological frameworks in the previous part of this paper is *not* meant to suggest that ethnographic and primatological perspectives are irrelevant. On the contrary: these two frameworks are needed in order to assess unique behaviour of extinct hominins. The problem is in the way these frameworks have been employed so far: however, they most empathically are *not* irrelevant.

This critique also does not mean that existing models for the evolution of cognition and the characterization of hominin minds have no value. Mithen's model for example (Mithen, 1996) in which he characterizes cognition as consisting of modular domains, with varying degrees of integration between different modular domains in different hominin species, is an extremely valuable heuristic device. It is to some degree hampered, however, by the too linear notion of progression from ape to modern human he incorporates in it. This results amongst others in a misinterpretation of the Neandertal mind, where the Neandertal mind is presented in a way that does not give this hominin enough credit with respect to its capabilities for the integration of cognitive domains. As the case study later in this paper will show, Neandertals and their predecessors were much better in their ability to assign objects to multiple categories, linking functions, locations and activities while assigning multiple meanings than Mithen's assessment grants them. The full heuristic power of Mithen's model will actually only be unleashed when the linearity is shed from his model. Applied against the backdrop of a branching tree model, it would become very powerful in describing the relations between the cognitive structure of prehistoric human minds and prehistoric human behaviour.

4. The implications: linear thinking, ‘modern behaviour’ and human ‘uniqueness’

With the problem clear, it becomes clear as well that there are certain implications when the ladder model of linear cognitive evolution (Fig. 2a) is substituted for a branching tree model (Fig. 2b).

In cladistic terminology, what is currently being taken into account in models for the evolution of cognition, are uniquely derived traits of cognition in *H. sapiens* as well as shared derived and shared primitive traits of cognition in the hominin family. Debate solely has evolved around the question whether particular aspects of cognition are uniquely derived for *H. sapiens*, or shared derived traits present in other, extinct hominins as well. What is notably missing from the discussion, are the uniquely derived traits of cognition of extinct hominins: these need to be taken into account as well.

This notably has implications for the meaning of “behavioural modernity”. The origins and meaning of “behavioural modernity”

are currently a primary focus when it comes to Late Pleistocene hominin evolution. At the moment, becoming “behaviourally modern” is treated as a distinct hominization event, much like the first appearance of tool use, fire use and bipedality. It is something believed to have raised *H. sapiens* above the rest, and as such the debate is a specific version of the bigger issue of ‘Human uniqueness’ (Cartmill, 1990) or “humaniqueness” (De Waal and Ferrari, 2010).

The current version of the debate largely has evolved around questions such as what does and does not constitute “modern behaviour” (Henshilwood and Marean, 2003; Langley et al., 2008; Wynn and Coolidge, 2009; Davidson, 2010 – and contrast the latter with McBrearty and Brooks, 2000), whether “modern behaviour” appeared suddenly, as a distinct event (e.g. Klein, 2008), or gradually over time (e.g. McBrearty and Brooks, 2000), and whether it originated in Africa and spread from there, or had a polyregional origin (e.g. Conard, 2008; Habgood and Franklin, 2008). In connection to this there is continuing discussion on whether “modern behaviour” has been restricted to *H. sapiens* (i.e. is a uniquely derived trait of the latter) or is a shared derived trait with other hominins as well, for example with our parapatric Eurasian sister species the Neandertal (e.g. Noble and Davidson, 1991, 1993; McBrearty and Brooks, 2000; D’Errico, 2003, 2008; Henshilwood and Marean, 2003; Henshilwood et al., 2004; Mellars, 2004, 2005, 2006; Hovers and Belfer-Cohen, 2006; Henshilwood, 2007; Zilhao, 2007; Conard, 2008; Klein, 2008; Langley et al., 2008; Norton and Jin, 2009; Belfer-Cohen and Hovers, 2010; Davidson, 2010; Texier et al., 2010; Zilhao et al., 2010).

It should be noted that most if not all of the mentioned scholars share the same implicit assumption that being “behaviourally modern” by definition equals to *occupying the top step on the ladder of cognitive evolution* (and this is why it still is such an issue whether, for example, Neandertals were capable of “modern behaviour” or not). Such a position can only be upheld from the perspective of a linear model of cognitive evolution which ignores the uniquely derived traits of extinct hominins. The implications of adopting a branching tree model of cognitive evolution (Fig. 2b) include that it will be perfectly viable to have two different kinds of complex cognition existing side by side without the one being superior to the other. Unlike the ladder model, a tree model does not automatically proclaim one particular “branch” of cognitive development (e.g. “modern behaviour”) to represent the top-level domain of cognition. While the ladder model dictates an inevitable superior-inferior dichotomy between “behaviourally modern” and “behaviourally non-modern”, the branching tree model does not. This is important to note, as a superior-inferior dichotomy is the main driver behind many contemporary explanations of the demise of the Neandertals and dispersal of *H. sapiens* (see Trinkaus et al., 2001 for a critique).

4.1. The checklist problem and a solution: the importance of unique behaviour

The implications go even further. As recognized by several scholars (e.g. Henshilwood and Marean, (2003); D’Errico, (2003); Langley et al., (2008); Wynn and Coolidge, (2009)), the debates on “behavioural modernity” have been too much framed in terms of satisfying a “checklist” of denominators believed to be key indicators for modern cognitive sophistication. There is clear disagreement about which denominators to include in this “checklist”, and there are questions about whether the employed lists of archaeological observations as such are effective measures of behavioural modernity at all (Henshilwood and Marean, 2003). In addition, the checklist-approach is often conducted with a double standard

towards the evidence when it comes to other hominins than *H. sapiens* (Roebroeks and Corbey, 2001).

While the problem is acknowledged by many, alternatives for such a checklist-approach are hard to formulate. This demonstrates the straightjacket the linear ladder model of cognitive evolution forces on interpretations of the archaeological evidence and the meaning of “behavioural modernity”. In the linear model, satisfying the criteria for “behaviourally modernity” is an essential litmus-test for assigning a top-level status of cognitive sophistication.

Only when linear thinking is discarded, and “behavioural modernity” regarded as just one out of several options at a potentially equal level of cognitive sophistication, true alternative solutions to a single-minded checklist can be formulated. Unique forms of (potentially high-level) cognition other than that of modern *H. sapiens* need to be identified and added to the equation: the uniquely derived traits of cognition of other hominins. This leads to an effective abandonment of a single-minded “checklist” based on modern *H. sapiens* alone for determining cognitive sophistication.

The paradigm shift outlined above cannot be made without changing the way researchers employ frames of reference. Turning to a branching model of biological and cognitive/behavioural evolution, it should by definition not be expected that patterns and relationships gleaned from ethnography or primatology alone can be used as a reference model to adequately assess the level of cognition of extinct hominins. The focus should shift towards finding and incorporating patterns that are unique for other hominins (their uniquely derived characteristics of cognition and behaviour). These are the patterns that are missed looking through ethnographic and primatological glasses only (see also Tooby and DeVore, (1987) and Potts, (1987)). It were these idiosyncrasies, more than either what they shared and what they lacked compared to *H. sapiens*, that characterized the hominin in question and sheds full light on the expression and complexity of their cognition (Langbroek, 2001). This means that the value of these idiosyncrasies in their own right has to be somehow assessed. This in turn requires developing methods to detect and interpret these idiosyncrasies.

4.2. Complications and benefits of a branching approach

Changing from the linear ladder model of cognitive evolution to a more modern, branching tree model admittedly makes things more complicated. It brings challenges, involving the need to create frames of reference totally independent from ethnography and primatology: frames of reference based somehow on the archaeological record itself.

That will not be easy, but it is possible. Kolen’s, (1999) ‘CLS hypothesis’ is a rare example of such an effort. His model for the diachrone centrifugal formation of semi-circular debris concentrations (‘Centrifugal Living Structures’, or ‘CLS’) by Neandertals, is an explicit attempt to create a model of unique spatial behaviour deduced from observations of the archaeological record itself. It is also a model, that potentially can (and should) be further tested against the archaeological record. Potts’ “stone cache” hypothesis for the Oldowan (Potts, 1988), is another example of a model trying to account for unique behaviour, and based in archaeological observations. Binford’s “Routed Foraging” concept (Binford, 1984:259–264) for the early *H. sapiens* inhabitants of Klasies River Mouth also was meant to provide a distinct alternative to ethnographically inspired central place models of hunter-gatherer foraging, even though it is uncomfortably close to a primate mobility model.

The potential benefits of shifting to such an approach and a branching tree model of cognitive evolution are large. It will mean that models of cognitive evolution get more in line with biological

models of evolution, and modern insights in evolutionary theory. Hence, it will lead to more mature models. It will create models structurally based on the character of the archaeological record, i.e. on the pertinent evidence. Moreover, the value of these models can be tested using the archaeological record. This is in stark contrast to the current situation: the linear ladder model is structurally immune to testing against the archaeological record, as it is a model where the structural preconceptions inherent to the model dictate interpretations of data, instead of data dictating interpretations and the structure of the model.

4.3. Where to look?

The areas to start looking for cognitive idiosyncrasies involve topics which have been long-standing, often fundamental problems. The 'Mousterian Problem' (Bordes, 1961, 1972; Binford and Binford, 1966; Bordes and de Sonneville-Bordes, 1970; Mellars, 1970; Binford, 1973, 1983; Dibble and Rolland, 1992), the 'problem' of what is behind recurrent patterns in assemblage variability in the Mousterian over long time spans, is an example. Binford (1989) characterized this variation as, "unlike anything known from the archaeological record of modern man". The Mousterian Problem has clear aspects of a situation where the understanding of the chronotopological structure of this period might be hampered by not giving full recognition to potentially unique ways of cognition, leading to unique ways of spatio-temporal and technological organization that are not well explained by sociological, functional and technological models gleaned from modern *H. sapiens* or extant apes.

Another area to look, one already touched upon above, is that of spatial organization at the site level. Does the Middle Palaeolithic genuinely lack intra-site spatial organization, or can it not be seen because it has its own unique spatial structure and complexity (e.g. Kolen, 1999), quite different from "modern" spatio-behavioural patterns gleaned from ethnography?

A third one is that of mobility strategies. Is a logistic way of resource procurement by means of a periodically moving central place strategy ('home bases') such as gleaned from modern ethnography the only option satisfying criteria for highly sophisticated planning and social interaction, or are other models possible? Does an absence of a strategy involving a central place necessarily equate to a lower cognition (in terms of strategies, planning, and social cognition)? These are assumptions often implicitly or explicitly made, but not warranted from a tree model perspective on cognitive evolution.

These are just a few topics out of many, but obviously very fundamental ones as these all relate to ongoing (and long-standing) major discussions in palaeolithic archaeology. Unique behaviours of Pleistocene hominins in these aspects get a quite different meaning when one drops notions that the "behaviourally modern" way of doing it is by definition the cognitively most sophisticated way of doing it.

5. A case study on uniqueness: mobility, handaxes and cognition at Boxgrove, UK

An example is provided through an excursion into the mobility patterns of the makers of Acheulean in Europe (presumably *Homo heidelbergensis*). Clues to hidden organizational aspects of mobility emerge when one looks at the *chaîne opératoire* of handaxe production in the Lower Palaeolithic of Europe. As a cautionary note before setting out with this case study, it must be explicitly stated that the pattern described below does *not* extend backwards into the Early Acheulean of Africa. The latter is a different phenomenon altogether, even though handaxes occur in both contexts. This is why the text uses "makers of Acheulean" above, not "makers of the Acheulean".

Boxgrove is a 0.5 Ma old Acheulean site in Sussex, UK, excavated during the 1980s and 1990s by the University College of London (Roberts and Parfitt, 1999). It is one of the earliest Acheulean sites of Europe. The site stands out because of its excellent preservation and minimal post-depositional disturbance. It basically constitutes a preserved palaeo landscape consisting of low-energy distal beach plain deposits (the Slindon Sands and Silts of the Goodwood-Slindon raised beach). The silt part of the deposits contains a palimpsest of abundant flint handaxes, debitage, a minor flake-core component, and faunal remains (including a hominin tibia and teeth). Refitting studies show that there has been minimal horizontal disturbance, the archaeology of the site retaining a large spatial *in situ* integrity (see Roberts and Parfitt, 1999 for details). Chronological integrity is high as well: the main archaeological unit probably represents a time span of no more than a few hundred years.

At Boxgrove, the finished handaxes (hundreds of them), handaxe production debitage, and handaxe resharpening flakes spatially occur together, as one assemblage. This has led some to view them as products of an *ad hoc*, on the spot "15 min culture", where flint nodules were extracted from the nearby chalk cliff, knapped into handaxes, used and then discarded, all in one process at basically the same spot (Gamble, 1999:121). That impression is wrong. Austin (1994) and Langbroek (2004) have pointed out the hidden mobility structure preserved within the Boxgrove palimpsest. They showed that handaxe production included at least three clearly distinct phases which are separated in both time and space, along a route through the landscape. Their argument will be briefly summarized below: for a more extensive treatment of the matter to a level beyond the scope of this case study, refer to Langbroek (2004).

This case study will focus on the handaxe-related archaeology and ignore the flake-core component. Basically, the handaxe-related part of the archaeological assemblage contains the following recognizable elements:

1. *decortication and primary reduction debitage*, the result of flint nodules being knapped into handaxe roughouts;
- 1a. occasional isolated roughouts;
2. *debitage* resulting from *thinning roughouts* (after the initial primary reduction stage) and *finishing* them into handaxes;
- 3a. Isolated *finished handaxes*, which at Boxgrove are usually ovate, thin and very symmetric;
- 3b. *resharpening flakes* (tranchets), some fitting to nearby handaxes but often not.

While all these elements can often be found in one and the same trench as a single assemblage, they represent distinct reduction phases, and geographically distinct activities (Austin, 1994; Langbroek, 2004). Sequences of primary decortication flakes constitute one group of refits. But these refitted sequences never extend to the products from the next phase of production in the same trench: that of thinning and finishing of handaxe roughouts into handaxes. Instead, the latter constitute distinctly separate refit groups (see Roberts and Parfitt (1999) and Langbroek (2004) for a discussion of several examples: in one very instructive case depicted in Pitts and Roberts (1997) a whole nodule could be refitted, but was left with a distinct handaxe roughout-shaped hole in the middle). These separate refitting thinning and finishing flake sequences not only never fit to sequences of primary knapping debris but in addition never fit to finished handaxes either. The only thing fitting to the finished handaxes found, are occasional tranchet resharpening flakes. In other words, the handaxes do not connect to the debitage from earlier phases in the production sequence of handaxes, and these earlier phases of handaxe production (roughout and thinning) in turn do not connect to each other either.

Hence, while all products of handaxe production from initial nodule decortication to final handaxe and resharpening debris are present in the archaeological assemblage, the individual substages of handaxe production at Boxgrove can be shown to be distinctly disconnected in space and time (ending up “together” only because the deposits are a palimpsest of numerous individual, non-connected events). Handaxe production at Boxgrove was split up into at least three spatio-temporally separate behavioural sequences and hence was *not* an *ad hoc* on the spot activity, but one coupled to a pervasive element of mobility and transport. These spatio-temporally separate behavioural episodes are (see Fig. 4):

- I. decortication and roughing out at time x at locality “Q”;
- II. thinning and finishing at time $x + 1$ at locality “R”;
- III. use of finished handaxes, sometimes with an additional resharpening sequence, at time $x + 2$ at locality “S”.

One additional piece of behaviour to note is that thinning flakes from sequence (II) were sometimes set apart and used for cutting tasks (as attested by edge wear, and refitting results showing how certain flakes were picked out and set apart from the rest of the debitage (Roberts and Parfitt, 1999)). Stage II is therefore not merely the thinning of a roughout to get a handaxe: it also represents the production of flakes for cutting tasks, using the roughout as a core. Roughouts hence were simultaneously blanks for handaxes *and* cores for flakes. This dual function is conceivably the very reason why the roughing out and finishing were split into spatio-

temporally separate activities instead of being conducted in one go at one locality.

Langbroek (2004) specifically argued against the notion put forward by Davidson and Noble (1993) that handaxes were accidental “byproducts” of flaking only (i.e. handaxes as “cores” rather than intentional “tools”, or the view that making a handaxe was never the intention with which the makers set out). In reality much of the “handaxe” is already incipient in the handaxe roughout shape, not the end product. At Boxgrove (and elsewhere, for example in the French Somme valley: see Langbroek (2004)) as shown this shape is created during a spatio-temporally distinct phase at locality “Q” *before* it is transported and used as a core and in that process turned into a handaxe at locality “R”. The outcome of a handaxe shape is initiated and defined distinctly *before* the reduction of the blank as a core starts, not *during* this phase. It is carried over to *beyond* this phase, as attested by the robust pattern of spatio-temporal removal of the next phase, handaxe discard, from the core use episode.

If handaxes were cores only with an accidental final “handaxe” shape when discarded, one would expect clear cases of thinning flakes fitting to handaxes, certainly at Boxgrove where handaxes were frequently discarded in still pristine conditions (e.g. Fig. 5).

Taken together, this strongly points out that the handaxe was a desired, intentional end shape, not an accidental outcome of a bifacial core flaking strategy. Even though handaxe roughouts were intentional cores at one specific part in the handaxe production sequence, they never were *only* cores, or even primarily cores. They were cores during a spatio-temporally distinct episode in their production sequence only, while simultaneously serving as a handaxe blank during this same episode.

One argument underscoring that the next transport phase, that of the finished handaxe from locality “R” to locality “S”, was

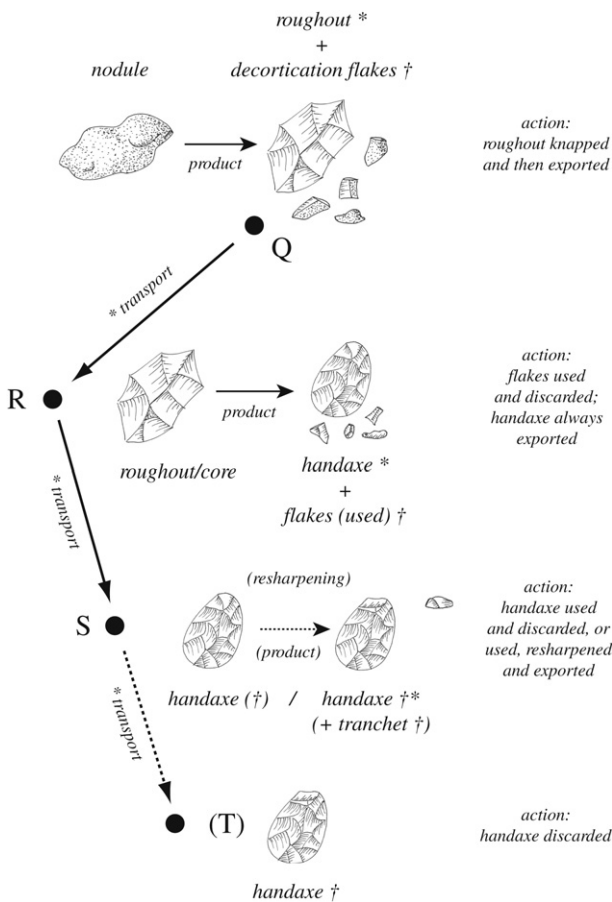


Fig. 4. Schematic representation of the itinerary involved in the chaîne opératoire of handaxe construction at Boxgrove. The itinerary starts at locality “Q” and involves at least two more localities “R” and “S”. It sometimes stretches even further (“T”). Legend: * items produced and exported. † items discarded.

Fig. 5. A fine ovate finished Boxgrove handaxe excavated in 1996. Without exception, no debitage from the thinning and finishing stages fits to finished handaxes at Boxgrove. Many Boxgrove handaxes such as this one were discarded in the near-pristine condition (photograph by the author).

planned rather than due to a pattern of unrelated incidental/habitual transport and re-use, comes from the combination of two observations: the in almost all cases pristine condition of the Boxgrove handaxes at final discard and invariable separation of their locations of discard from their production debris. If transport was merely habitual (as opposed to planned), most of them would continue to be repeatedly transported (in unrelated episodes) until finally discarded when worn out, such as is the case for example with habitually transported chimpanzee hammer stones (Carvalho et al., 2008:159–160). At Boxgrove, that is distinctly not the case. Handaxes were invariably transported, yet almost invariably still pristine upon discard. This argues against a “habitual” transport scenario where tools get transported by virtue of being available for transport, until worn out.

How does this case study tie in to cognition and unique patterns of behaviour? The reconstructed spatio-temporal behavioural sequence provides a clue regarding the spatial cognition and the cognition behind mobility at Boxgrove. Handaxe manufacture sequence episodes I to III create a virtual *itinerary*: starting at location “Q” where the flint nodule undergoes primary reduction; anticipating the use of the flaking products of the created half-fabricate at locality “R”; anticipating the use of the created end product (the handaxe) at yet another locality “S”; and possibly stretching to several more localities beyond that, as attested by the presence of isolated handaxe resharpening flakes. “R” and “S” are already implied and anticipated by the activities at locality “Q”: hence it can be said that the itinerary “Q” to “R” to “S” was already in place in the mind of the Boxgrove hominins at locality “Q”. The knapping of a roughout at “Q” hence equals the creation of a virtual task-scape of different anticipated activities to be performed at different spots in the landscape. Interestingly, at Boxgrove (and other roughly contemporary European Acheulean sites (Langbroek, 2004)) the construction of this itinerary through the landscape is tied to a strategy where an artefact sequentially changes character and takes on multiple roles, starting as a blank/core that produces flakes to cut with the blank/core in that process fluidly transforming into a large cutting tool. The robustness of the pattern and the involvement of a transport phase commencing after the production of a distinct half-fabricate/core product but before it is actually “used” as a core and tool blank, strongly suggest that this pattern of mobility was formalized to a very high degree, indicating that it was planned.

One thing to note is that this creation of an itinerary and transport of half-fabricates/cores and tools took place in a landscape with ample, good quality raw materials available at any given spot: it occurred while hominins were moving along a beach plain flanked by chalk cliffs containing seams of high quality flint that stretched for more than 30 km (Roberts and Parfitt, 1999). That is a point to consider: at any given point in this landscape segment, hominins could easily have procured good quality flint from the nearby chalk and knapped these flint nodules to create flakes or handaxes for use *ad hoc*, on the spot. Instead, in the vast majority of cases they chose to prepare a core/handaxe roughout in advance and transport it, a strategy with a complex duality where a “core” produces flakes and at the same time is a blank transformed into a large cutting tool (a handaxe) in the process. They never just produced and discarded a handaxe on the same spot. This puts even more emphasis on the planned itinerary aspect involved in the production of handaxes. It also points to a cognitive release of the technological aspect of mobility from raw materials availability in the landscape: at Boxgrove, the two are independent and considerations other than ubiquitous raw material availability in the landscape shaped the technological management of stone in the chosen mobility strategy.

It is the latter that makes this pattern different from Binford's (1984) “routed feeding” or “routed foraging”, even though both

the Boxgrove pattern and the “routed foraging” concept involve itineraries. Binford's “routed foraging” (basically a chimpanzee mobility model: see below) involves minimal planning depth, being framed in terms of an opportunistic “take along as you go” during an opportunistic “feed as you go” subsistence strategy. He specifically mentions a lack of long-term planning behind the procurement of raw materials (Binford, 1984: 262). At Boxgrove, raw materials are procured as part of a strategy that involves planning over several activities and localities in the future, in a landscape where the ubiquitous raw materials distribution does not force such planning. This is quite different from the “routed foraging” concept of Binford.

As mentioned above, other considerations than a minimal mental map of stone resource availability in the landscape must have shaped the spatio-temporal planning of stone tool production, use and discard. Which other aspects those are, is an interesting aim for future research. Another interesting issue is whether the release of the character of stone tool technology from raw materials availability in the landscape coupled to the construction of a planned itinerary and a task-scape, can be argued to be a step towards the construction of a cultural geography (cf. Binford, 1987).

The Boxgrove situation is quite different from what is seen with chimpanzees, where links between technology, planning and tool transport amount to the transport of materials from the nearest tool resource to a given food resource, with no indication of extended planning beyond this (Boesch and Boesch, 1983, 1984; Boesch-Achermann and Boesch, 1993; Sanz et al., 2004; Carvalho et al., 2008). This is behaviour which is structured along and constrained by a minimal mental map of resource availability (Boesch and Boesch, 1984; Normand and Boesch, 2009). Transported chimpanzee tools with only few exceptions primarily serve only one function (70%–100% of the cases of transported tools among the wild chimpanzee communities at Bossou and Dieké: Carvalho et al., 2008: 156). Only unintentional products (flakes unintentionally, i.e. by accident, struck from anvils or hammers) on rare occasions get a new function (Carvalho et al., 2008: 161). By contrast, at Boxgrove the roughouts systematically serve multiple functions (being core, and tool blank at the same time, with roughouts/cores fluidly transforming into a new tool, a handaxe, during use), and this is a strategic element in the mobility pattern. At Boxgrove, there is a systematic pattern of “tools produced from tools” as part of an extended mobility strategy, a pattern that chimpanzee material culture lacks.

At the same time, the Boxgrove “itinerary-foraging” strategy appears to be different from what is known of modern hunter-gatherer mobility strategies, in that there is no evidence for it being part of a mobility system involving a “central place”. “Home bases” remain elusive features of the Lower and Middle Palaeolithic record. With the (in the author's opinion genuine, not apparent) absence of convincing evidence for “home bases”/“central places”, the itineraries created by the Boxgrove hominins served in a quite different context than the itineraries created by modern hunter-gatherers during logistic expeditions from a “central place”. The Boxgrove itineraries were created as part of a mobility system that therefore appears truly idiosyncratic.

6. Mobility, tools and cognition at the Maastricht-Belvédère quarry, the Netherlands

The pattern described here for Lower Palaeolithic Boxgrove at 0.5 Ma in many ways foreshadows similar strategies employed by Neandertals and their immediate predecessors in the Middle Palaeolithic (the Mousterian) between 250 and 35 ka. At Maastricht-Belvédère in the Netherlands, low-energy distal floodplain sediments from the Palaeo-Meuse system dated to about 240

ka(MIS 7) yielded a rich industry including Levallois and non-Levallois technology. Refitting studies show that the artifacts occur *in situ* with mostly minimal post-depositional disturbance, as at Boxgrove (Roebroeks, 1988; Roebroeks et al., 1992; De Loecker, 2006). The archaeological deposits contain relatively rich localized “patches” of artifacts, which are present against a low density “scatter” of artifacts that covers the palaeolandscape like a veil (Roebroeks et al., 1992; see also Isaac (1981) for the “scatters and patches” approach). The low density “veil” largely consists of discarded tools that were imported from elsewhere as they generally do not refit to production waste, and limited sequences of knapping debris (the production of a few flakes from an imported core). Evidence of tool resharpening is another aspect of the “veil”. In essence, the “veil” is a palimpsest of a countless number of individual events involving tool use, resharpening, limited flake production for cutting tasks and tool discard. Cortical flakes are very rare, and complete reduction sequences are absent. This is an analogue to the sets of (used) handaxe finishing flakes, finished handaxes, and resharpened handaxes plus resharpening flakes at MIS 13 Boxgrove. By contrast, the rich localized “patches” are characterized by large amounts of primary decortication and flaking debris, as well as tools. Many tools present at these sites however do not refit to the flaking debris and they are often made on different raw materials than the flaking debris. At the same time, refitting of the primary flaking debris suggests cores and tools left these sites, as these end products are absent. There is a clear element of import of finished tools from other places, part of which actually could be part of the “veil” of tools scattered over the palaeolandscape and hence totally unrelated to the primary debitage patches (Roebroeks et al., 1992). And there is a clear element of export of cores and tools to other places from the primary debitage patches. These exported cores and tools end up as imports in the “veil” (Roebroeks, 1988; Roebroeks et al., 1988, 1992). They are analogues to the exported handaxe roughouts and handaxes at Boxgrove.

Patterns of transport such as occur at Maastricht-Belvédère and patterns of raw materials provenance, as described for example by Geneste (1985) for the Middle Palaeolithic of the Aquitaine, are hence similar to the Acheulean pattern at Boxgrove. Like the handaxe roughouts at Boxgrove, there is a pattern where cores and flake blanks produced at locality “Q” are exported in order to produce flakes and tools for cutting tasks at locality “R”, tools that often are transported in finished state to yet another locality “S”. As with the *chaîne opératoire* of the Boxgrove handaxes, the creation of a core or tool in the Maastricht-Belvédère rich “patches” seems to have equaled the creation of an itinerary along multiple localities in the mind of the Neandertal that made it. There is a fluidity similar to the Boxgrove roughout/core fluidity in the Maastricht-Belvédère core component. Refitting evidence shows that cores frequently undergo typological change during their reduction process (De Loecker, 2006). The conspicuous use of *éclats débordants*, (typologically the result of prepared core rejuvenation) as cutting tools such as discussed by Roebroeks et al. (1992), appears to be a fluid concept where something is both a preparatory part of a reduction sequence and tool at the same time. Producing an *éclat débordant* created both a tool and a renewed source of flakes. This is similar to the purpose of handaxe roughouts at Boxgrove. The fact that the *éclats débordants* at Maastricht-Belvédère appear as solitary objects in the “veil”, without cores or production debris fitting to them, suggests they were transported (Roebroeks et al., 1992), just like the finished handaxes at Boxgrove.

In Pleistocene Europe, the Lower Palaeolithic hominins that created the European Acheulean and their Late Pleistocene descendants, Middle Palaeolithic Neandertals, employed mobility systems that involved the creation of pre-planned itineraries

through the landscape, but without evidence that these originated in a “central place”. They appear to have moved from sleeping locality to sleeping locality on a near-daily basis along itineraries during which they procured material resources and food resources in a spatio-temporally planned fashion. Aspects of their lithic technology and raw materials management were tied in to that mobility strategy, with the creation and employment of a transported core/tool component extending and fluidly evolving along the chosen itinerary. This is a mobility system that is unknown among either modern hunter-gatherers, or extant apes. It is truly unique. The intricate ways in which raw materials procurement, tool creation, fluid change of tool character and tool use are embedded within these itineraries, attest to a complex cognition, resulting in complex behaviour of a unique kind.

7. Summary and conclusions

To summarize: the evolution of cognition in human evolution is still approached according to a linear evolution model, even though modern insights in phylogenetic evolution favour a branching tree model. This mismatch between models for phylogenetic and cognitive evolution is largely the result of the frames of reference employed to reconstruct cognitive evolution. These include a referential framework that is ladder-like with primates at the bottom and modern *H. sapiens* at the top. The linear model is reinforced by linear models of brain size evolution. It ignores that the evolution of the brain should be tied to phylogenetic lines (and hence show a branching tree pattern). It also ignores that brain organization, including post-natal ontogenetic aspects of brain development, is as important for cognition as is brain size: similar sized brains can differ in these aspects, leading to profound differences in cognition.

The structure of the linear model for cognitive evolution is not fundamentally based in either modern evolutionary theory or the archaeological record. It is actually immune to testing against the archaeological record. Adoption of a branching tree model for cognitive evolution on the other hand will yield models with a structure which is testable against the archaeological record and in line with modern insights in evolutionary theory. Adopting a branching tree model has some profound implications, notably for the meaning of “modern behaviour” in terms of cognition relative to hominins that do not show fully “modern” behaviour. Unlike the ladder model, a tree model does not automatically proclaim one particular “branch” of cognitive development (e.g. “modern behaviour”) to represent the top-level domain of cognition. In order to understand cognitive evolution, abandonment of linear views means more emphasis should be put on discerning unique forms of cognition and behaviour in the archaeological record (the uniquely derived traits of cognition and behaviour of *all* hominins, not just *H. sapiens*). That is a challenge.

As a final remark, and one that links to the presented case studies of planning and tool production in the Lower and Middle Palaeolithic of Europe, letting go of a linear ladder model means one has to be prepared to find, perhaps, that all those ‘behaviourally modern’ aspects that make us feel unique, are not at all what we currently make out of them in terms of the level of “our” cognition compared to that of, for example, Neandertals. That, might be the largest obstacle to some, as it directly refers to the policing of boundaries regarding a perceived “Human Uniqueness”(Cartmill, 1990): as can be seen for example from the constant redefinition of what constitutes “modern behaviour” now more and more evidence emerges of behaviour once considered “modern” in anatomically non-modern hominins as well (see Davidson (2010) for a summary, and one version of what is “modern behaviour”). We should be prepared to seriously consider that the cognition of some extinct hominin species was at an equal level to ours, even

though it behaviourally expressed differently and might have focused on different aspects of cognition than we do, yielding quite different but appropriate, sophisticated and complex strategic decisions and associated behaviour.

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