“15 Minutes of Fame”: Exploring the temporal dimension of Middle Pleistocene lithic technology

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Received 18 October 2004; accepted 9 March 2005

Abstract

This paper addresses the spatial and temporal dimensions of knapping routines through analysis of refit data. Many reconstructions of lithic tool production utilising refit data concentrate upon ‘how’ a piece of stone is taken apart, and less often consider the ‘when’ and ‘where’. Lower Palaeolithic artefacts are frequently viewed as belonging to simplistic technical systems in which tools were made and used as and when required, showing little temporal depth. Modern knappers can replicate the components of the Acheulean toolkit, such as a biface, in around 15 minutes. The predominant use of local raw materials and the relatively simple reduction sequences observed on many Middle Pleistocene sites has given rise to the view that Acheulean hominins possessed an immediate approach to technology, and that artefacts did not stay in the technological system very long. In contrast, other researchers have stressed the increased planning abilities of hominins in relation to their stone tool-making and using routines. Increased planning abilities are often cited as a diagnostic feature of modern human cognition. As such, tracing the emergence of these abilities is an important avenue of research in human evolution. The aim of this paper is to investigate how the process of lithic production was organised on several Middle Pleistocene sites in northwest Europe. By comparing refitting sequences from several primary context sites, the different stages of reduction present at these locations can be reconstructed. Since refit sets record the work carried out in one place and time by an individual, they can be used to reconstruct the spatial and temporal dimension of these past technological activities. The analysis shows fragmentation of reduction sequences was a common occurrence, suggesting a more dynamic approach to tool-making and using activities than has previously been recognised. The analysis provides a description of these artefact dynamics, and discusses the underlying cognitive mechanisms of this behaviour.

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Keywords: Middle Pleistocene; Palaeolithic; Refitting; Planning; Cognition

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Introduction

Research on the origins of modern humans dominates palaeoanthropology. Within the research field, ‘modernity’ can be defined in different ways depending upon the focus of the research. Palaeontologists are concerned with defining criteria for anatomical modernity (e.g. Schwartz and Tattersall, 2000; Lieberman et al., 2002; Stringer, 2002; White et al., 2003), archaeologists with evidence for behavioural modernity (e.g. Binford, 1985; Stringer and Gamble, 1993; Mellars, 1996; McBrearty and Brooks, 2000), and evolutionary psychologists with cognitive modernity (e.g. Donald, 1991; Dunbar, 2000). The relationship between these three elements of modernity is central to the debates on the origins of modern humans. The most dominant paradigm, the so-called “Upper Palaeolithic Revolution”, places the origins of modern humans late in our evolutionary history, at 40-50 Kya throughout the Old World. This hypothesis suggests that anatomical, behavioural and cognitive modernity were brought together for the first time, producing the ‘explosion’ of cultural remains including art, personal ornaments, organised campsites and new lithic and bone technology (Binford, 1985, 1989; Mellars, 1991, 1996; Noble and Davidson, 1991, 1996; Klein, 1995, 2000; Mithen, 1996). This view has been heavily criticised for giving an extremely Eurocentric view of human evolution (McBrearty and Brooks, 2000). These researchers have argued that the components used as markers of modernity do not occur suddenly in a cultural explosion. Rather there is a gradual assembling of the ‘package’ of modern human behaviours in Africa from 250-300 Kya (McBrearty and Brooks, 2000). In this respect, McBrearty and Brooks (2000) echo the arguments of researchers working in the earlier Palaeolithic, who have always emphasised continuity in the record, and discussed the emergence of individual abilities rather than the ‘whole package’ (e.g. Isaac, 1977, 1986; Wynn, 1979, 1993; Gowlett, 1984, 1995, 1996a,b, 2002; de la Torre et al., 2003).

This paper focuses upon one particular aspect of hominin cognition often cited as a marker of modernity, that of planning abilities. Through analysis of refit data, routines of technological behaviour are reconstructed, giving an insight into the cognitive abilities underpinning these behaviours. The traditional methods of identifying planning in the archaeological record are critically assessed, and suggest that current views on hominin planning abilities need to be revised.

Plans and behaviour

“We are planning agents. Our purposive activity is typically embedded in multiple, interwoven quilts of partial, future-directed plans of action. We settle in advance on such plans of action, fill them in, adjust them, and follow through with them as time goes by. We thereby support complex forms of organisation in our own, temporally extended lives and in our interactions with others; and we do this in ways that are sensitive to the limits on our cognitive resources.’ (Bratman, 1999:1).

Cognitive scientists have argued that modern human behaviour is structured and guided by plans (Miller et al., 1960; Hoc, 1988). Plans are defined as hierarchical processes that can control the order in which a sequence of operations is performed, in the context of solving a problem (Miller et al., 1960:16). Two different aspects of planning can be distinguished based upon the different types of information processed — procedural knowledge and declarative knowledge (Anderson, 1980). Procedural knowledge refers to knowledge about ‘how’ to do things (e.g. if X, then Y), whereas declarative knowledge refers to knowledge about facts (e.g. A causes B). Both declarative and procedural knowledge are integral to plan execution in modern human adults, and are preceded by intention. Declarative knowledge involves the formation of a mental representation, and allows a degree of flexibility in decision-making behaviour that the procedural knowledge does not (Shettleworth, 1998). Planning abilities in modern humans emerge during ontogenic development, from simple procedural plans situated in action to declarative planning regulated entirely in
anticipation (DiLisi, 1987). Comparative studies have shown higher order primates use procedural planning in their daily activities (e.g. Kohler, 1927; Boesch and Boesch, 1984). These plans are situated in action and are goal directed. What has been commonly referred to as ‘planning’ in modern humans is more accurately defined as the ability to plan ahead, beyond context-bound, functional procedures that are immediately executed in order to satisfy a present need, such as hunger or thirst. Several different cognitive abilities are combined to enable this kind of future planning. These include the ability to simulate in an inner environment, the formation of detached representations, understanding causal relationships, a concept of future time, and the ability to keep a goal ‘in mind’ (working memory) whilst carrying out secondary goals (Gärdenfors, 1996; Visalberghi and Limongelli, 1996; Suddendorf and Corballis, 1997; Koechlin et al., 1999; Atance and O’Neill, 2001).

It has been suggested that monkeys show ‘myopia for the future’ (Roberts, 2002), and lack the ability to relate events causally, thus are unable to foresee the consequences of their actions (Visalberghi and Limongelli, 1996). In contrast, humans and (more controversially) apes demonstrate the ability to extract declarative knowledge from experience and to make hypotheses about the outcome of future actions (Visalberghi and Limongelli, 1996; Boesch and Boesch-Achermann, 2000). These abilities are not just confined to foraging activities, but are also important in negotiating social relationships, which may have been the driving force for selection of these forward planning abilities (Barrett et al., 2003). Whilst some non-human primates may show some of these abilities in social contexts e.g. tactical deception (Byrne and Whiten, 1992), their tool-making and using activities appear to be constrained in the present. On current evidence, only modern humans appear to combine these cognitive abilities to plan ahead during technological activities, enabling much greater control over our external environment. When did this ability to plan ahead during technological activities develop, and how can we trace it in the archaeological record?

Archaeological approaches to planning

Organisational abilities, and the degree of ‘planning depth’ are attributes that have previously been considered as useful markers of modernity in the archaeological record (Binford, 1985, 1989; Schick, 1987; Toth, 1987; Roebroeks et al., 1988; Kuhn, 1992, 1995; Noble and Davidson, 1996; McBrearty and Brooks, 2000). These discussions, greatly influenced by Binford, have often centred upon ‘curation’, with a presence or absence of curated technology interpreted as indicating a presence or absence of planning abilities. Binford (1989) argued that in the archaeological record curated technology can be distinguished by differential raw material selection, resharpening of tools, complicated tool designs, long-distance tool transport and differential discard patterns (Binford, 1989:20-21). The (supposed) absence of these attributes in the Lower Palaeolithic have propagated the view that Acheulean hominins did not have a curated technology, and therefore by inference lacked planning abilities. However, these arguments are flawed as they fail to establish a causal link between the suite of behaviours know as ‘curation’ and the underlying cognitive mechanisms involved in forward planning. Modern humans can plan to be expedient, and comparative studies have shown that apes often engage in behaviours that could be described as curation that do not necessarily involve planning ahead (McGrew, 1992). Curation is a tactical choice that can be employed to ensure the use of tools in situations where it may otherwise not be possible to have them. Many other factors, including functional considerations, environmental and geological conditions affect the need to curate tools (Duke, 2003). Therefore, the presence or absence of evidence for curation cannot be used as a simple proxy for the presence or absence of planning abilities in hominins.

Temporal scales of lithic production

Although a modern knapper can replicate a biface or reduce a nodule of flint into usable flakes in around 15 minutes, is this an accurate
analogy of how hominins organised their knapping activities? At some archaeological locations, this does appear to have been the case. For example at Caddington, UK, bifaces and biface manufacture flakes from all stages of reduction have been recovered, leading the excavators to conclude “It is quite apparent that they [the bifaces] were made and abandoned on the spot” (Bradley and Sampson, 1978:89). At Quarry 2 Area A, Boxgrove, UK, a flint nodule was carried a few hundred metres onto the mudflats and flaked in situ, allowing almost complete reconstruction of the original nodule (Bergman and Roberts, 1999). These examples represent very ‘precise moments in time’ (Roe, 1981), where tool production appears to have been carried out over a very short duration in reaction to an immediate need. This has led to some commentators to characterise pre-Homo sapiens as possessing a ‘15-minute culture’ (e.g. McCrone, 2000:34), concluding that technological activities were highly situational, with hominins lacking the cognitive abilities to anticipate and plan for the future (Pettitt and Schumann, 1993; Noll and Petraglia, 2003).

But is this a fair assessment of how Middle Pleistocene hominins approached their tool-making and using routines? Were all tools made, used and discarded in this ‘15 minute’ manner? What were the temporal scales of hominin tool-making and using activities, and what can these reveal about their underlying cognitive abilities?

In order to answer these questions, we need to be able to rekindle the internal time dimension of past behaviour, unlocking the spatial and temporal dimension of lithic production and use. This may appear to be a difficult undertaking when dealing with Palaeolithic assemblages, which often represent an accumulation of time-averaged material rather than discrete episodes of behaviour (Binford, 1981; Stern, 1993). Even so, these assemblages can give some information about the spatial — and therefore temporal — separation of tool making and using activities. For example, the large Acheulean site of Kilombe, Kenya, preserves hundreds of bifaces in primary context (Gowlett, 1993). These bifaces were not made in the immediate area, and were transported and discarded at this location by their hominin makers, sometimes after a certain amount of trimming. This site provides unambiguous evidence for at least one episode of transport from the place of manufacture to the place of final discard, with the possibility of multiple episodes of transport and use en route. Although the temporal scale of the production and use of these bifaces is difficult to assess, the site provides clear evidence that bifaces were not made, used and discarded in the same location, suggesting at least some temporal ‘segmentation’ between the different phases of production, use and discard (Gowlett, 2002). A similar situation is also found in the Olorgesailie palaeolandscape, where highly localised, dense concentrations of bifaces occur (Isaac, 1977; Potts et al., 1999). The reduction of bifaces at Tabun demonstrates several phases of resharpening (McPherron, 2003), suggesting long histories of modification.

In Europe, large primary context Acheulean sites preserving hundreds of bifaces comparable to Kilombe or Olorgesailie appear not to exist. These differences are partly connected to the different palaeoenvironments of Africa and Europe during the Pleistocene. In Africa, stable land surfaces were present for hundreds or even thousands of years, allowing the build-up of archaeological material. These stable land surfaces were then sealed relatively quickly by volcanic ash or lava, ensuring the preservation of the palaeo-land surface and providing a means of absolute dating. In contrast, terrestrial sedimentation in the European Pleistocene was generally episodic, characterised by short pulses of high sedimentation separated by long intervals of stasis and/or erosion (Roebroeks and Tuffreau, 1999). Therefore, many open-air sites are effectively ‘snapshots’ of short duration, although it is difficult to quantify precisely the exact duration of occupation or the number of separate occupations (Conard and Adler, 1997). However, the differences may also be indicative of how lithic technology was organised. It has been demonstrated that transport of raw materials and artefacts was carried out on African ESA sites since Oldowan times, although the nature and significance of this behaviour has been widely debated (Toth, 1985; Schick, 1987; Potts, 1988, 1991; Noble and Davidson, 1996,
Kimura, 1999; Potts et al., 1999). In the flint rich regions of northwest Europe, raw material for tool manufacture was relatively plentiful and ubiquitous. In early interglacial conditions, the landscape would have presented a readily accessible source of flint in the form of fluviatile and outwash gravels left behind by the retreating glaciers (Wenban-Smith, 1998), removing the need for long distance raw material transport. During full interglacial conditions, the access to good-quality raw materials would become more restricted, with gravels becoming silted over and vegetated (Wenban-Smith, ibid.). It is probable that flint would only have been available at points of natural exposure through erosional processes and secondary deposition, principally at the margins of river channels, serving as important locations for raw material procurement. In these environments, raw material acquisition could be embedded in more general subsistence activities (cf. Binford, 1979), since river valleys were not only important as raw material sources, but also for other essential resources such as water, edible plants and game. Although raw material accessibility would have been restricted in this manner, this situation would still enable reactive or opportunistic artefact production and use since raw materials were always close by, negating the need for long-distance transport. Previous interpretations of European Lower Palaeolithic sites have concluded that knapping activities were carried out in response to immediate needs, with little planning depth standing behind the technology (Bradley and Sampson, 1978; Binford, 1985; Bergman et al., 1990). These conclusions are based upon very specific evidence as outlined above, or negative evidence i.e. the lack of evidence for curation. Artefact transport, if indeed it did occur, is difficult to recognise due to the difficulties of sourcing flints, and the problems of distinguishing between local flints derived from secondary deposits. Therefore, another approach must be adopted to understand the assemblage dynamics in these regions.

In this paper, I want to move away from the concept of curation and the presence/absence debates, as I (along with several others) consider these unhelpful for understanding planning abilities and cognition (Hayden, 1976, Sackett, 1982; Marks, 1988; Nelson, 1991; Gamble, 1995; Nash, 1996; Odell, 1996; Hallos, 2004). An alternative approach is to investigate routines of tool manufacture and use in order to identify levels of planning in technological activity (Gowlett, 1986, 1995, 1996a, 2002; Parker and Milbrath, 1993). This approach, following a theoretical framework developed by cognitive science, analyses sequences of action and identifies decision points that structure and guide behaviour (Miller et al., 1960; Hoc, 1988). This approach is particularly apt for lithic technology, since it is a reductive process which leaves behind durable products, the production of which can be retraced through refitting and replication studies. The advantage of such an approach is that it allows the choices made by hominins in the course of technical acts to be assessed. Rather than emphasising ‘how’ raw materials are worked, it is the decision points relating to ‘when’ and ‘where’ tool making and use occurred that are of major concern here. Exploring the temporal dimension of knapping routines provides a unique insight into the planning processes of the hominin makers in respect to their technological activities. Quantifying the temporal depth of knapping activities may help to differentiate between action for immediate needs, and action orientated towards future needs. Evidence knapping activities were orientated towards future needs would suggest hominins had the cognitive abilities required for planning ahead beyond the immediate context for action.

**Refitting method**

Most primary context sites in Europe are characterised by an abundance of débitage indicative of manufacturing activities, and a much smaller proportion of formal tools. Several of these sites preserve *in situ* knapping scatters with the presence of refits. Refitting sequences record specific actions carried out sequentially in time and in the same location, giving an insight into how an individual knapping episode was organised. This approach has been highly successful in interpreting open-air sites of Middle Palaeolithic age, for
example Maastricht-Belvédère (Roebroeks, 1988; Roebroeks and Hennekens, 1990; De Loecker, 1992) and Wallertheim (Conard and Adler, 1997).

Several factors other than hominin behaviour can affect the number and type of refits present in an assemblage. Post-depositional forces such as fluvial winnowing will remove smaller pieces of débitage, isolating larger pieces and creating fragmentation of reduction sequences that are unrelated to hominin activities (Schick, 1986). Rigorous taphonomic analyses are needed to determine these effects before any inferences can be made about behaviour. The number of refits found in an assemblage is more often a reflection of the amount of time (and consequently funding) that has been invested in the refitting program, rather than a reflection of patterning produced by hominin behaviour. Some of the most successful refitting programs are those which have been undertaken over a long time period and employed many researchers e.g. Maastricht-Belvédère (Roebroeks, 1988; De Loecker, 1992) and Boxgrove (Bergman et al., 1990; Roberts and Parfitt, 1999). Finally, is it not realistic to expect to find 100% nodule reconstruction from archaeological assemblages, since an excavated assemblage merely represents a sample from a much larger spread of lithic material discarded on a Palaeolithic landscape (Foley, 1981). Ethnographic studies have shown that the spatial scale of activities carried out by modern hunter-gatherer groups occurs over a much larger area than most Palaeolithic excavations are carried out (O’Connell et al., 1992). Therefore, the fragmentation of refitting sequences may be caused simply through sampling bias.

In order to address these problems, a comparative, site-based approach is used in this analysis. The excavation of these assemblages has been carried out using controlled scientific methods, and each site has undergone detailed taphonomic analysis, showing the effects of post-depositional disturbance are minimal. The sites have been excavated and analysed by several different researchers, in order to reduce observer errors. Therefore, any patterning in the assemblages should reflect real behaviour relating to the choices made by hominins in relation to their knapping activities. If complete refitting sequences are preserved in one location, this would suggest tool manufacture, use and discard was a continuous process, with tool behaviour confined to only making and using tools for an immediate task. If segments of the process are preserved, this would suggest the production of tools was interrupted both spatially and temporally. Depending upon which segments of the process are present in an assemblage will inform as to which activities were carried out on-site and at which point in the knapping routine action was interrupted. This does not just apply to the knapping process, but also the wider behavioural repertoire and tool production in relation to use. Analysing patterns of refits in this way provides an insight into how hominins organised their knapping routines, and enables discussion of the underlying cognitive mechanisms of this behaviour.

The sites

This analysis compares the patterns of refits from four sites dating to the Middle Pleistocene of northwest Europe (Table 1). All sites are Acheulean in character, with evidence of core and flake working and biface manufacture. The specific lithic assemblages chosen from each site were done so primarily for their undisturbed, primary context character as suggested by taphonomic

<table>
<thead>
<tr>
<th>Site</th>
<th>Lithic assemblage</th>
<th>Area excavated m²</th>
<th># of artefacts &gt; 2 cm</th>
<th>OIS</th>
<th>Climatic conditions</th>
<th>Topographic position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beeches Pit AH (fresh)</td>
<td>75</td>
<td>1812</td>
<td>11</td>
<td>Full interglacial</td>
<td>River bank</td>
<td></td>
</tr>
<tr>
<td>Elveden Area III</td>
<td>44</td>
<td>1000</td>
<td>11</td>
<td>Early interglacial</td>
<td>River bank</td>
<td></td>
</tr>
<tr>
<td>Cagny-L’Epinette H (fresh)</td>
<td>200</td>
<td>1218</td>
<td>10/9</td>
<td>Early glacial</td>
<td>River bank</td>
<td></td>
</tr>
<tr>
<td>Ferme De L’Epinette MS</td>
<td>2500</td>
<td>1075</td>
<td>10</td>
<td>Early glacial</td>
<td>High plateau</td>
<td></td>
</tr>
</tbody>
</table>

Table 1
Summary of site contexts
analysis (Tuffreau et al., 1995; Andresen et al., 1997; Tuffreau et al., 1997a; Ashton et al., 2000). It is accepted that none of the assemblages included in this analysis can be considered to be totally undisturbed in situ occurrences, and are probably more accurately described as buried surface collections than precise moments of the past (cf. Binford, 1987:20). These assemblages do exhibit many characteristics that are consistent with minimal site disturbance, such as their occurrence in fine-grained, low energy sedimentary contexts, the abundance of small sized débitage, the fresh condition of artefacts and the presence of several refitting groups with a tight spatial distribution. These characteristics indicate that the general patterning observed can be confidently attributed to the choices made by hominins in relation to the management of their lithic resources.

**Refitting studies**

Extensive refitting programmes have been carried out on the assemblages by several different researchers. Refitting studies on the Beeches Pit assemblage were primarily carried out by the author (Hallos, 2002) and T. Pumphrey (Pumphrey, 1995), with preliminary results published in Andresen et al. (1997), and Gowlett and Hallos (2000). The Elveden assemblage is under analysis by N. Ashton and colleagues at the British Museum, London (Ashton et al., 2000; Ashton et al., in press). Refitting of the Cagny L’Epinette and Ferme de L’Epinette assemblages was carried out by A. Lamotte of the University of Lille and the Musée départemental de Préhistoire, Arras, France (Tuffreau et al., 1995; Tuffreau et al., 1997a; Lamotte, 1999). For this analysis, the refit groups from each assemblage have been classified in accordance with the categories established by Cziesla (1990), summarised in Table 2. Other attributes, including size, raw material type, amount of dorsal cortex and platform characteristics were also recorded. These data were collected to ascertain the different types of reduction strategies present, the stage(s) of reduction represented by the refit sets, and the completeness of the reduction sequences. Detailed technological descriptions of the refits for each assemblage have been published elsewhere (cited above and references therein), and therefore will not be repeated here. The main characteristics of the refits groups for each site are summarised in Tables 3-7, which form the basis of the comparative analysis.

**Comparative analysis**

By comparing the refitting sequences in the assemblages, certain patterns have emerged. In all the assemblages, two main reduction strategies could be identified through the refitting sets, one relating to core and flake production and one relating to biface manufacture (Figs. 1 and 2). These are not the only reduction strategies employed by hominins at these locations, since Levallois reduction is present at Ferme De L’Epinette Level MS, and the ad hoc retouching

<table>
<thead>
<tr>
<th>Table 2</th>
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</thead>
<tbody>
<tr>
<td>Refit classification following Cziesla (1990).</td>
</tr>
<tr>
<td><strong>Dorsal/Ventral</strong></td>
</tr>
<tr>
<td><strong>Break</strong></td>
</tr>
<tr>
<td><strong>Artefact Modification</strong></td>
</tr>
</tbody>
</table>
of frost-flakes is observable at Beeches Pit Area AH and Cagny-L’Epinette Level H. However, refits relating to these reduction strategies are not present within the assemblages, and therefore they will not be elaborated on further in this discussion.

The proportion of refits in the assemblages varies between 2.5-15% (Table 3). This overall variation is due to a combination of factors, including taphonomy and sample size, before knapping behaviour can be considered. The lowest number of refits are found at Cagny L’Epinette Level H, at only 2.5% of the total assemblage. This is likely due to fluvial disturbance removing elements of the reduction sequence, since the fresh, refitting pieces are found within a level containing more abraded artefacts. This suggests that although the artefacts were excavated from a discrete horizon resembling an undisturbed knapping area, the accumulation of lithics at this location has a long and complex depositional history (Dibble et al., 1997). For the other assemblages in this analysis, it is likely that taphonomic effects have had a minimal impact upon the numbers of refitting pieces. This is evidenced by the spatial distribution of the refitting pieces, which do not show any strong preferred orientations at Beeches Pit or Ferme De L’Epinette, usually a sign of significant natural disturbance (Bertran and Texier, 1995). At Elveden Area III, the refits show a preferred orientation on an east-west axis, although this may be due to the elongation of the excavation trench in the same axis (Ashton et al., in press). The overall size distributions for the assemblages are also consistent with minimal disturbance, with a high proportion of debitage <2 cm, some of which are incorporated into refitting sets. It is probable that the artefacts in all assemblages have moved slightly, due to movements downslope, trampling and bioturbation. However, these slight disturbances have not significantly affected the overall content and character of the assemblages.

The highest number of refitting pieces are found at Ferme De L’Epinette Level MS, which is also the largest excavation in terms of area. This implies that to a certain extent, the total number of refits in an assemblage is dependent upon the size of excavation. Since all excavations are a sample of material discarded on a landscape (cf. Foley, 1981), the larger the excavation, the greater the chances of recovering more ‘complete’ sequences of behaviour. However, it is noteworthy that the majority of refits from Level MS come from an area approx. 25 m², (Tuffreau et al., 1997a:527), an area comparable to the size of the excavated areas at the other sites. Even more

<table>
<thead>
<tr>
<th>Site</th>
<th># of refit groups</th>
<th># of individual artefacts</th>
<th>Mode # of pieces per group</th>
<th>Maximum # of pieces per group</th>
<th>% Of total assemblage</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP AH</td>
<td>31</td>
<td>102</td>
<td>2</td>
<td>28</td>
<td>6.0</td>
</tr>
<tr>
<td>ELV III</td>
<td>44</td>
<td>139</td>
<td>2</td>
<td>8</td>
<td>14.0</td>
</tr>
<tr>
<td>LEP H</td>
<td>11</td>
<td>33</td>
<td>2</td>
<td>8</td>
<td>2.5</td>
</tr>
<tr>
<td>FEP MS</td>
<td>44</td>
<td>145</td>
<td>2</td>
<td>12</td>
<td>15.0</td>
</tr>
</tbody>
</table>

Table 4
Summary of refit types

<table>
<thead>
<tr>
<th>Site</th>
<th>Break</th>
<th>Dorsal-Ventral</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>BP AH</td>
<td>9</td>
<td>30</td>
<td>21</td>
</tr>
<tr>
<td>ELV III</td>
<td>20</td>
<td>45</td>
<td>24</td>
</tr>
<tr>
<td>LEP H</td>
<td>3</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td>FEP MS</td>
<td>6</td>
<td>14</td>
<td>37</td>
</tr>
</tbody>
</table>

Table 5
Comparison of pair distances between refitting pieces

<table>
<thead>
<tr>
<th>Site</th>
<th>Pair distance between refitting pieces (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>BP AH</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>ELV III</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>LEP H</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>FEP MS</td>
<td>&lt; 0.1</td>
</tr>
</tbody>
</table>
significant is that very few pieces recovered from outside this ‘concentrated’ zone can be refitted to pieces from within the zone, suggesting that the vast majority of knapping was carried out in a very limited area. At Elveden Area III, the smallest excavated area in the sample, the proportion of refits is still quite high at 14%. Therefore, although size of excavation is important, there is not a simple relationship between excavation size and number of refitting pieces at these sites. Whilst it cannot be denied that both taphonomy and size of excavation affect the total number of refits present in an assemblage, these factors alone cannot totally explain these differences. This becomes more apparent when the types of refit present in each assemblage are compared.

The three types of refit classified by Cziesla (1990) — breaks, dorsal-ventral and modification refits — are found in different ratios in the assemblages (Table 4). Break refits mainly concern flakes and cores broken in production because of natural flaws in the flint. Examination of the break surfaces shows that the majority are patinated to the same degree as the rest of the artefacts, demonstrating that the breaks are ancient and occurred at or soon after the time of manufacture. Flint is a heterogeneous material, with each nodule containing internal flaws and weaknesses that cause flakes to shatter spontaneously as they are detached from the core. The spatial distribution of the broken refits also supports this interpretation, since in the majority of cases the broken artefacts are separated by only a few centimetres (Table 5). The breaks occur at the time of production, and rarely are tools broken in the context of use in these areas. Refits relating to artefact modification are extremely rare in the assemblages, suggesting that these activities were not carried out in these areas, or are less visible and associated with a lower discard rate. A third possibility that cannot be discounted at this stage, especially for the Beeches Pit and Elveden assemblages which are still undergoing analysis, is a lack of these types of refit due to the difficulty of finding them, as they usually involve very small flakes.

Dorsal-ventral refits, reconstructing parts of reduction sequences are the most abundant type, accounting for 80% of all refitting groups. This indicates that primary production activities are highly visible in the archaeological record and account for a high proportion of discarded materials at these locations. However, complete (or near-complete) nodule reconstruction is not commonly observed, and there are relatively few refit sets with high numbers of flakes indicating long sequences of flaking in a single location. Figure 3 shows the majority of dorsal-ventral refits in all assemblages are 2 or 3 pieces from a sequence of knapping, and appear ‘orphaned’ (Morrow, 1996) from the other flakes and/or core in their sequence of production. The incompleteness of refitting sets appears to be a product of the interruption of the reduction sequence at various different stages.

The dorsal-ventral refit groups bring together a variety of elements (Table 6). At every site, conjoining sets of flakes are the most abundant refitting elements, accounting for over 50% of all refit groups in any one assemblage. This demonstrates flakes from the same episode of reduction are most likely to be discarded at the same location. Relatively low numbers (0-18%; Table 7) of cores are incorporated into refitting sets, indicating cores were not always flaked and
discarded in one location, with very few of the refitting groups having complete nodule reconstruction. The patterning observed in the refit groups suggests cores were transported and flaked at various locations within the landscape. The removal of cores is observed at Beeches Pit Area AH, Cagny-L’Epinette Level H and Ferme De L’Epinette Level MS, as evidenced by the presence of refitting decortication flakes isolated from their cores. This interpretation is also supported by the high flake to core ratio in most assemblages and relatively high ‘flake recovery rate’ (Villa, 1983) for each assemblage (Table 8). It is probable that the cores removed from the excavated areas were flaked in various other areas where activities are below the threshold of archaeological visibility. Often when cores are discarded with their debitage, they appear to have been very minimally flaked, as observed at Beeches Pit Area AH, or introduced to the excavated area partially knapped as at Ferme De L’Epinette Level MS and Elveden Area III, with the refits recording the final

Fig. 1. Summary Model of Biface Reduction Sequence.

Fig. 2. Summary Model of Core Reduction Sequence.
sequences of flaking and discard. Ferme De L’Epinette has the lowest flake to core ratio and flake recovery rate, suggesting a high proportion of the cores knapped at this location were also discarded on site.

Flake tools are present at the majority of locations, and appear to be produced and discarded in the same area, reflecting an expedient strategy of production. Retouched flake tool production is low on all sites, with all sites having less than 10% of available blanks transformed into retouched tools (Table 9). Conjoining sets of flakes including retouched pieces show the flake blanks selected for retouch are derived from cores knapped in situ at some locations. At Ferme De L’Epinette Level MS, flake tools are produced on blanks derived from imported cores, revealing how transported elements of technology (cores) facilitate expedient tool manufacture and use (flake tools). The imported cores at Ferme De L’Epinette give an insight into a possible function for transported cores, providing a ready supply of flake blanks to facilitate expedient flake tool production.

Refits relating to biface manufacture can be divided into three different groups, each relating to a different stage of production. Firstly, biface-shaping flakes can be related to minimally flaked bifaces or rough-outs that have been discarded at a premature stage of production. Secondly, conjoining shaping and thinning flakes are found in isolation from their resulting bifaces, suggesting export of the bifacial pieces from these locations for use and discard elsewhere. Thirdly, trancheet flakes refitting to the tips of bifaces suggest resharpening activities in the final phases of use before discard, on bifaces that were imported into these locations already shaped.

Complete sequences of flaking in a single location are not commonly observed, and when these do occur they are often related to minimally flaked pieces and rough-outs abandoned in various stages of production. Often these pieces are discarded owing to flaws in the raw material, leading to discard of the unfinished biface with its flakes of production. The discard of these elements together suggests they were abandoned during the manufacturing process, and in effect represent the residues of knapping ‘failures’. If these attempts at biface manufacture had been successful, it seems highly unlikely they would have fallen out of the technological system at these locations.

Biface transport occurs at several stages during the manufacturing process, creating spatial and temporal disengagement of the knapping routine.

Table 8
Core:Flake Ratios and Flake Recovery Rates

<table>
<thead>
<tr>
<th>Location</th>
<th># Cores</th>
<th># Flakes</th>
<th>Flake:Core Ratio</th>
<th># Scars on Cores</th>
<th>Flake Recovery Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP AH</td>
<td>54</td>
<td>919</td>
<td>17.0</td>
<td>268</td>
<td>342.9</td>
</tr>
<tr>
<td>ELV III</td>
<td>33</td>
<td>517</td>
<td>13.0</td>
<td>172</td>
<td>249.4</td>
</tr>
<tr>
<td>LEP H</td>
<td>51</td>
<td>795</td>
<td>15.6</td>
<td>194</td>
<td>409.8</td>
</tr>
<tr>
<td>FEP MS</td>
<td>81</td>
<td>810</td>
<td>10.0</td>
<td>492</td>
<td>164.6</td>
</tr>
</tbody>
</table>

1 Including fragments and biface rough outs.
2 The total number of flakes is calculated by adding the number of whole flakes, proximal ends and retouched flakes (each count as 1 flake) and flakes split laterally (each count as 0.5).
3 The number of flakes is expressed as a percentage of the number of scars, known as the “flake recovery rate” (after Villa, 1983:151).
At some sites, the early stages of manufacture are present, with the flaking and discard of rough-outs as observed at Beeches Pit Area AH and Elveden Area III. In other cases, more complete flaking is observed, with shaping and thinning also taking place before export of the bifacial pieces, as seen at Elveden Area III and Ferme De L’Epinette Level MS. The introduction of bifaces into areas for further reduction/use before discard is a frequent occurrence, seen at Beeches Pit Area AH, Cagny-L’Epinette Level H and Ferme De L’Epinette Level MS. The ‘passing through’ of bifaces at locations is also observed, as evidenced by resharping flakes unrelated to the bifaces discarded in these locations. The refit data shows that knapping routines were interrupted at various different points, and the production and use of bifaces was not a continuous process from beginning to end in one sitting. These observations support previous studies which have suggested bifaces were transported elements of the toolkit, in some cases undergoing multiple episodes of transport and resharping before discard (Hayden, 1976; Keeley, 1980; Ashton and McNabb, 1994; Austin, 1994; McPherron, 2003). However, it is important to emphasise that not only are finished bifaces transported, but also bifaces in various stages of manufacture. This suggests a greater temporal depth is involved in their production than a ‘15 minute’ approach to technology.

It is apparent from the comparative analysis that breaks occur in the reduction sequences, and that core elements are moving in and out of the excavated areas. Could these patterns be explained in terms of sampling biases, or are they documenting real spatial fragmentation of knapping activities? If so, what are the scale of these movements and what can they reveal about hominin planning abilities?

Due to the relatively small area — in behavioural terms — of the archaeological excavations in this analysis (and in general), it is possible that the fragmented pattern of reduction is one falsely created by sampling bias. If these excavation trenches were to be expanded, would this reveal more complete sequences of reduction? Three lines of evidence can be used to address this issue. Firstly, in every assemblage it is the core elements that are moving in and out, showing a consistent pattern of fragmentation. This suggests a more deliberate strategy underpinning this pattern than pure chance. If sampling bias alone was creating the segmentation, it would be expected to occur at random, rather than at particular points within the sequence, repeated at every location. Secondly, the largest excavated area in this analysis is Ferme De L’Epinette Level MS, at 2500 m². If sampling bias is a major factor in creating fragmentation of reduction sequences, this site should, in theory, have the most ‘complete’ sequences of flaking. Whilst Level MS has the highest proportion of refitting pieces, it also has the most fragmented sequences, with the greatest number of flake pairs isolated from the rest of their reduction sequence (Fig. 3). Biface production at this site is also highly fragmented, with no evidence for complete sequences of manufacture (Fig. 7 and Table 12). In contrast, Elveden Area III, which is the smallest excavation area at 44 m², has some of the least fragmented sequences of flaking, with the highest number of cores included in refit sequences than any other assemblage (Table 7 and Fig. 5). Thirdly, the spatial distribution of refits shows that in all sites, the majority of refitting pieces are found in areas of most dense artefact concentration, and have pair distances under 3 m (Table 5). This demonstrates that individual knapping episodes were generally static and carried out in one particular area. Ferme De L’Epinette Level MS is the only location where pair distances between refits exceeds 10 m. The maximum distance between refitting pieces and size of excavation is

<table>
<thead>
<tr>
<th>Site</th>
<th>Total number of blanks available</th>
<th>Total number of retouched blanks</th>
<th>% Of blanks transformed into retouched tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP AH</td>
<td>919</td>
<td>21</td>
<td>2.3</td>
</tr>
<tr>
<td>ELV III</td>
<td>517</td>
<td>13</td>
<td>2.5</td>
</tr>
<tr>
<td>LEP H</td>
<td>795</td>
<td>54</td>
<td>6.8</td>
</tr>
<tr>
<td>FEP MS</td>
<td>811</td>
<td>74</td>
<td>9.1</td>
</tr>
</tbody>
</table>

1 The total number of blanks is calculated by adding the number of whole flakes, proximal ends and retouched flakes (each count as 1 flake) and flakes split laterally (each count as 0.5).
obviously linked, since the distance between refits cannot exceed the size of the excavation. However, these long-distance refits are rare, and the majority of refits at Level MS follow the same pattern as refits at the other locations, with pair distances less than 3 m. As stated previously, most of the refits at Level MS come from a concentrated area of 25 m² (Tuffreau et al., 1997a:527). Very few pieces from outside this zone can be conjoined to pieces within this area, therefore the ‘missing’ pieces from the refit sets from the main concentration were transported further away than a few metres. Significantly, the most complete refitting sets are found within the concentrated zone, and all have pair distances of less than 2 m (e.g. group AB in Tuffreau et al., 1997b:235). There are a small number of refits separated by distances of 10-20 m, predominantly flakes transported short distances before discard, probably in the context of use rather than hominins moving short distances while knapping. These three lines of evidence would suggest that the fragmentation of reduction in these assemblages is created by hominin interruption of knapping routines, rather than a pattern falsely created by sampling bias. This is not to say that the size of the excavation is not a factor in affecting the number and types of refits found in an assemblage, but from the evidence presented here, it does not appear to be the major causal factor in the fragmentation of individual reduction sequences.

The scale of artefact transport is more difficult to quantify from the sample data. It is clear that local segmentation is occurring, although this could be anything in the range of a few hundred metres up to several kilometres. Long distance transport of ‘exotic’ raw materials does not occur, although this is not surprising given the abundance of good quality local flints. If the hominins could fulfil their raw material needs with local materials in the course of daily foraging activities, there would be no need to transport stone long distances. The selection and transport of artefacts, even over relatively short distances, suggests that technology was embedded within other routines. The cognitive implications of this are discussed below.

The segmented nature of the refit groups in every assemblage attests to the spatial and temporal fragmentation of reduction sequences, with the transport of cores and bifaces accounting for the incomplete refitting sequences observed at these locations (Table 10 and Figs. 4-7). Although many sites have a full range of artefacts relating to all stages of reduction, refitting has shown that these products are not the result of the same reduction sequence from start to finish in one location (Tables 11 and 12). Long sequences of flaking, relating to core reduction or biface manufacture can only rarely be reconstructed in any one location. Rather, the majority of the knapping residues relate to segments of separate reduction sequences that ‘dropped out’ of the technological system at these locations. These segmented patterns are not simply the result of sampling bias or post-depositional effects. These patterns are repeated at every site, which have been excavated under controlled scientific conditions and analysed by several different researchers, suggesting the patterns are real phenomena and relate to the choices made by hominins in the organisation of their lithic technology.

Discussion - implications for planning abilities

The analysis has demonstrated that spatial and temporal fragmentation exists in the knapping routines of Middle Pleistocene hominins. Furthermore, the interruption of individual reduction sequences was not arbitrary or random, and was repeated in every assemblage, showing a consistent pattern of behaviour.

In any technologically aided activity, a tension exists between acquiring suitable raw materials, making an appropriate tool and applying that tool to a particular activity. The products of knapping must be placed within their systemic context (cf. Schiffer, 1972). Knapping is not an end in itself.
but rather a sub-goal in the course of foraging activities. The greater the time interval between the current action and the goal requires increased cognitive ability to think ahead. Increasing the temporal depth of knapping routines requires the knapper to keep the overall goal ‘in mind’ whilst executing the sub-routines necessary to achieve the goal. Recent research in neuroscience has shown that keeping a goal ‘in mind’ while processing secondary goals is especially well developed in modern humans as compared to other primates, and involves the most anterior part of the frontal lobes (Koechlin et al., 1999). Previous analyses of lithic reduction may have underestimated the planning abilities of the knapper since they have tended to concentrate upon procedural plans and see the products of knapping as the goal, rather than a sub-goal in the wider context of foraging activities. Replication studies, which are often used to understand ‘how’ a particular knapping sequence was executed may be partly responsible, as they are not explicitly concerned with the temporal

Fig. 4. Artefact Dynamics at Beeches Pit Area AH.
scale of production. For a modern knapper replicating a Palaeolithic tool, the goal is to make the tool. However, the context of production is very different to that of the hominin, who was making the tool in order to carry out some other activity(ies). As shown by the refit data, only rarely were complete reduction sequences carried out in a single episode or location, as is the case in a replication experiment. This suggests the hominin technological system was much more dynamic, with knapping activities carried out over an extended duration and requiring increased planning abilities than has previously been recognised.

There is evidence that some knapping activities were orientated towards immediate needs, as inferred from previous studies. The almost complete reconstruction of nodules and the production and discard of flake tools in the same location attest to knapping activities carried out in a reactive context. However, these ‘immediate return’
activities (Woodburn, 1980) are relatively rare, and are embedded within a more complex technological system of lithic production and use. At every site there is also evidence that the knapping routines were temporally extended beyond the production of tools for immediate use, suggesting orientation of knapping activities towards future needs. Individual reduction sequences were frequently interrupted, with tools transported and knapped at various locations within the landscape. These patterns show that knapping activities were extended beyond the ‘15-minute culture’ commonly associated with these assemblages. The dynamics in these assemblages are not immediately apparent, and it is only through the analysis of refitting sequences they are revealed (Figs. 4-7).

Core reduction sequences were commonly interrupted after the decortication stage and cores were removed from the areas where the initial
reduction took place. Cores that had undergone a considerable amount of flaking elsewhere were also introduced into sites, flaked and discarded. Biface reduction sequences are highly fragmented in time and space, attesting to a high degree of mobility in the technological system. Not only were finished bifaces transported around the landscape, but also bifaces in various stages of production. This suggests that the production of bifaces was not in response to some immediate ‘cue’, such as the presence of a carcass. What can these artefact dynamics reveal about the underlying cognitive mechanisms of this behaviour? In order to demonstrate the presence of forward planning abilities, there must be dissociation of a future mental state from the current one, and action must be taken to ensure a future need will be satisfied independently of the present need (Clayton et al., 2003). In modern comparative studies, this “requires anticipation of future events

Fig. 7. Artefact Dynamics at Ferme De L'Epinette Level MS.
over a timescale of at least hours, if not longer” (Clayton et al., 2003:690). Therefore, if strict criteria are applied, the segmented reduction patterns do not provide unequivocal evidence that these hominins could plan for the future. It is not possible to quantify the precise length of time between the production of tools and their use from this dataset. The scale of transport is within a local range, therefore it could be argued that tool production and use was practically continuous, with some spatial segmentation due to the practicalities of carrying out a particular task. In the archaeological record, distance is the most common way to measure time, with long-distance movements indicating greater lengths of time. But this does not mean that all local movements of tools were necessarily done in a continuous manner. It can be demonstrated that tool production was a multi-episode activity, and the process could be halted at various stages, requiring the knapper to keep the overall goal in mind whilst executing the sub-routines of manufacture. It has also been demonstrated that the segmented reduction patterns are not simply a factor of sampling bias, therefore this segmentation is a product of the decision to transport artefacts at various stages. This temporal extension of knapping activities demonstrates a greater cognitive capacity than a purely opportunistic approach to technology. It would appear that by preparing and transporting cores and bifaces, hominins were equipping themselves with a stone resource in anticipation of their future tool requirements.

It has been argued that the transport of tools does not involve any deliberate planning ahead, and can be explained as habit acquired by observational learning (Noble and Davidson, 1996:167). However, it is difficult to explain the pattern of tool transport in this study area unless hominins could conceive of a future need for tools, given it is an environment where stone was relatively abundant. Another argument might be that tools were produced to service some immediate need, then casually conserved as other opportunities for use presented themselves, rather than producing tools with prior intentions in mind. This kind of tool transport has been documented in chimpanzees, who carry termite fishing sticks from one termite mound to another in the course of foraging (Goodall, 1986). However, this hypothesis does not easily explain the patterns of fragmented reduction and transport observed in these lithic assemblages. The most compelling evidence against such an explanation is the choice of tools — cores and bifaces — that were consistently prepared and transported. The refitting sequences show bifaces were not often made in single episodes of reduction in a single location, so could not have been made for a particular use and then casually carried around afterwards. Cores also appear to have been deliberately ‘prepared’ for export by removal of cortex at

<table>
<thead>
<tr>
<th>Nodule testing</th>
<th>BP AH</th>
<th>ELV III</th>
<th>LEP H</th>
<th>FEP MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decortication</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flake production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core discard</td>
<td></td>
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</tbody>
</table>
some locations, rather than used to produce flakes in one location and casually transported to another. Cores themselves are generally not viewed as finished ‘tools’ (cf. Toth, 1985), rather they are a source of flake tools, and have to be used in combination with a hammer to produce usable flakes. A suitable hammer would also have to be carried in order for a core to be knapped, so it is difficult to see how this would happen ‘by chance’. The relatively rare occurrence of hammers on these sites, and Palaeolithic sites in general, suggests hammers were also transported (Table 13). The consistent selection of these items in different contexts is a strong counter argument to claims that tools were transported without intent. These transport patterns demonstrate hominins had a detached representation of future needs in respect to their tool making and using behaviour. This would require the knapper to be aware of the future goal (whether specific or general), whilst executing the current knapping activity. This includes carrying tools ‘just in case’, since this also requires a concept of future needs, or else the current action of carrying the tool becomes meaningless.

More traditional measures of planning abilities, such as long distance transport of raw materials and extensive resharpening of tools are absent in these assemblages, and could be used to argue that this provides evidence for the lack of these abilities. However, lithic assemblages must be interpreted in context, as other factors such as the availability of raw material will affect whether tools are curated or not. In the study region, flint is relatively abundant, therefore it is not surprising that tools are not transported long distances as such behaviour was not necessary. This may also account for a lack of intensive resharpening activities, since where raw materials are plentiful, it may have been a more successful strategy to produce a new tool rather than resharpen an existing one. It could be argued that it would actually be ‘less intelligent’ to curate tools long-distances in these environments. The strategy of ‘maintaining’ a ready supply of flakes by transporting core and hammerstones is conceptually little different to resharpening, as in effect both are prolonging the ‘use-life’ of the raw material. The fragmented reduction sequences and selection of particular tools illustrates tool-making and use was not simply reactive, and shows a level of planning that is not immediately apparent from looking at more traditional measures of planning abilities.

Other aspects of tool-making behaviour also suggest that hominins were extracting and using

<table>
<thead>
<tr>
<th>Parts of biface reduction sequence represented by refitting groups</th>
<th>BP AH</th>
<th>ELV III</th>
<th>LEP H</th>
<th>FEP MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughing-out</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biface shaping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biface thinning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finishing/resharpening</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biface discard</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
declarative knowledge about their environment, giving rise to greater flexibility in the behavioural repertoire. The decortication of nodules before transport would help to lower weight and therefore the overall energetic costs of carrying. Removing cortex would also enable the knapper to assess the quality of the raw material before investing energy in transport. The discard of knapping ‘failures’ reveals they had standards of what was an acceptable tool and what was not, and an understanding of the properties of raw materials.

Although it is difficult to state unequivocally that the results of this analysis show hominins had the cognitive abilities enabling future planning, it is also equally difficult to argue these abilities were entirely absent. This is not to suggest that the planning abilities of Middle Pleistocene hominins were exactly the same as modern humans, but it appears that in some aspects they display abilities that are within the modern range. Research by Dunbar (1998, 2000, 2004) relating primate and hominin neocortex size and ‘theory of mind’ (ToM) abilities lends support to this hypothesis. It is proposed that ToM — the ability to understand another’s mental state, is an emergent property of more fundamental cognitive abilities, also required for forward planning (Barrett et al., 2003). Dunbar (2000) has proposed that the extent to which ToM abilities are constrained is directly dependent upon the size of the neocortex — a simple function of how much neural circuitry is available for processing. Plotting ToM abilities of living primates against neocortex size produces a linear relationship between monkeys, apes and humans (Dunbar, ibid.). Using fossil endocasts to estimate hominin neocortex size (Aiello and Dunbar, 1993), predictions can be made about the timing of ToM abilities in the hominin lineage. Using this methodology predicts that by the Middle Pleistocene, the neocortex size of archaic Homo sapiens, or Homo heidelbergensis, would have been capable of fourth-order intentionality, well beyond the abilities of other nonhuman primates, and within the modern human range (Dunbar, 2000). Therefore, the evidence for increased planning in technological activities is compatible with these predictions, since the cognitive abilities required for forward planning are necessary for the emergence of ToM. How far back along the hominin timeline these abilities can be traced is difficult to assess. It is known that from the Oldowan onwards, transport of tools and raw materials takes place, although taphonomic effects blur the resolution. It has also been demonstrated that many of the so-called ‘manuports’ identified in the Olduvai sequence are actually the product of natural accumulation (De La Torre and Mora, 2005), raising the possibility that manuports on other sites may not have been transported by hominins after all. Refitting can give a very precise ‘snapshot’ of activity, although unfortunately most of the early Pleistocene record is not amenable to this type of analysis. From the limited data available at present, it would appear that tool production in the Oldowan was carried out on-the-spot (e.g. Roche et al., 1999; Semaw, 2000), although the low numbers of assemblages with refits makes this hypothesis difficult to test. Other lines of evidence, such as raw material transfer distances suggests small-scale transport of artefacts was a key component of early technology (Toth, 1985; Potts, 1991; Kimura, 1999; Potts et al., 1999). Technological analysis of the Olduvai and Koobi Fora lithic assemblages demonstrates repeated and consistent patterns of artefact transport, suggesting the Oldowan was not simply a reactive or expedient technology (Toth, 1987; Kimura, 1999, 2002; Braun and Harris, 2003).

The question of how to translate a hypothesis about essentially unobservable internal processes into hypotheses about observable behaviour to differentiate unambiguously between competing explanations is a major issue in comparative studies of cognition (Shettleworth, 1998). The advantage of modern cognitive science is that it can carry out experiments on subjects and refine those experiments to help distinguish between hypotheses.

Table 13
Numbers of hammerstones in each assemblage

<table>
<thead>
<tr>
<th>Assemblage</th>
<th># hammerstones</th>
<th>% Of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP AH</td>
<td>6</td>
<td>0.3</td>
</tr>
<tr>
<td>ELV III</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>LEP H</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FEP MS</td>
<td>8</td>
<td>0.7</td>
</tr>
</tbody>
</table>
archaeology, the subjects (hominins) cannot be tested directly, and therefore we have to make inferences about their cognitive abilities from the traces of behaviour manifest in the archaeological record, with all its inherent biases. Cognitive abilities attributed to later hominins are often denied in earlier hominins, based on similar evidence. This suggests our willingness to accept one hypothesis over another changes not with stronger evidence, but a preconception of the timing of the emergence of modern abilities.

Conclusions

The preceding analysis has examined a particular aspect of cognition — planning abilities — with refitting data. The study suggests that traditional methods of identifying planning in the archaeological record have overplayed the importance of curation, and have therefore underestimated the planning abilities of Middle Pleistocene hominins. The study has shown that analysis of refitting sequences is not only important for understanding ‘how’ a piece of raw material was taken apart, but also allows the spatial and temporal dimension of knapping activities to be addressed. Such analyses are also revealing on other Middle Pleistocene sites more complex routines of artefact production and use were carried out than previously recognised, such as the horse-butcher site GTP17, Boxgrove, UK (Pope, 2004).

The refit data demonstrates spatial and temporal fragmentation existed in the knapping routines of the hominin makers. The segmented reduction patterns are not random or context specific, and similar patterns on each site suggest a strategy underpinning these decisions about ‘when’ and ‘where’ to make tools. The strategy involved producing cores and bifaces for use in other locations, and therefore suggests a greater temporal depth to tool-making and using activities than a ‘15-minute’ approach. There appears to be an emphasis on producing tools for future needs, suggesting planning abilities extending beyond the immediate context of action. This is strong evidence that Middle Pleistocene hominins were planning ahead their technological activities and anticipating their future needs for tools. These behaviours require cognitive abilities within the modern human range, such as understanding causal relationships, detached representation, a concept of future time and keeping a goal in mind over time (working memory) whilst processing secondary goals. This suggests the cognitive abilities underlying future planning developed earlier in our evolutionary history than the appearance of anatomically modern humans and the ‘Upper Palaeolithic Revolution’. The evidence for increased planning depth in the archaeological record during the Middle Pleistocene supports the arguments that the cognitive mechanisms enabling ToM developed early in our hominin lineage and are closely related to increases in neocortex size (Dunbar, 1998, 2000, 2004).

Understanding hominin cognition through analysis of lithic data is by no means a straightforward undertaking. When analysing archaeological data from a cognitive perspective, the problem lies with establishing the causal link between observed behaviours and their underlying cognitive mechanisms. This is also true in modern cognitive science, and definitions of concepts such as planning, anticipating, projecting, future thinking etc., are constantly being refined and updated (Clayton et al., 2003; Suddendorf and Busby, 2003). Only through a multidisciplinary approach, bringing together archaeological evidence and cognitive theory can we begin to understand and trace the emergence of these abilities.

Acknowledgements

I would like to thank John Gowlett for his continued support for this research. Funding was provided by the British Academy Centenary Research Project ‘From Lucy to Language: Archaeology of the Social Brain’, and data collection was carried out as part of a PhD thesis funded by the AHRB. I am very grateful to Alain Tuffreau and Agnès Lamotte for access to the Cagny assemblages, and to Nick Ashton for permission to study the Elveden collection and for providing access to unpublished data. Many thanks go to Ignacio de la Torre, who provided helpful comments on an earlier draft of the manuscript.
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