Pleistocene Exchange Networks as Evidence for the Evolution of Language

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Distances of raw-material transportation reflect how hominid groups gather and exchange information. Early hominids moved raw materials short distances, suggesting a home-range size, social complexity and communication system similar to primates in equivalent environments. After about 1.0 million years ago there was a large increase in raw-material transfer distances, possibly a result of the emergence of the ability to pool information by using a protolanguage. Another increase in raw-material transfer occurred during the late Middle Stone Age in Africa (after about 130,000 years ago), suggesting the operation of exchange networks. Exchange networks require a communication system with syntax, the use of symbols in social contexts and the ability to express displacement, which are the features of human language. Taking the Neanderthals as a case study, biological evidence and the results of computer simulations of the evolution of language, I argue for a gradual rather than catastrophic emergence of language coinciding with the first evidence of exchange networks.

Recent work by archaeologists has focused on how the first evidence of modern human behaviours such as symbol use may be evidence for language (Noble & Davidson 1996; Mithen 1996). While the pursuit of symbolic behaviours in the archaeological record leads to mostly robust claims about language emergence, they risk producing a rather coarse-grained scenario. Renfrew's (1996) Sapient Behaviour Paradox suggests that while a group may be capable of a certain level of cognitive ability, individuals may never manifest those abilities in a way that will be directly recognizable by archaeologists. As a consequence, the dated evidence for 'sapient' behaviour may be much more recent than the first appearance of this behaviour.

The aim of this article is to present a model for the evolution of language using distances of raw-material transfer. The model is based on Whallon's (1989) suggestion that language and alliance networks co-evolved during the Upper Palaeolithic. This provides an alternative to those models focusing on traditional evidence of modern human behaviour such as symbolic artefacts and complex artefact re-duction sequences. The model focuses on the relationship between hominid communication systems and the ability of hominid groups to exploit resources. Using raw-material movement data as a parallel inquiry into the emergence of modern human abilities such as language it is possible to refine and strengthen the argument for the emergence of modern human behaviours in Africa sometime before 100,000 years ago.

Distances of raw-material transfer are compared from African and European sites between 2.5 million to 20,000 years ago. An 'occurrence' of a raw-material transfer is defined by one or more associated artefacts made from a raw material that can be sourced to a specific location. For example, one occurrence can be a single chert artefact that is sourced to an outcrop 5 km away, or several hundred pieces of obsidian in the same stratigraphic context that can be sourced to an outcrop 40 km away. I define language as communication that involves syntax, use of arbitrary bi-directional symbols and expression of displacement (Aiello 1998, 23). Syntax is the hierarchical structuring of words or phrases within sentences so that relationships between multiple subjects
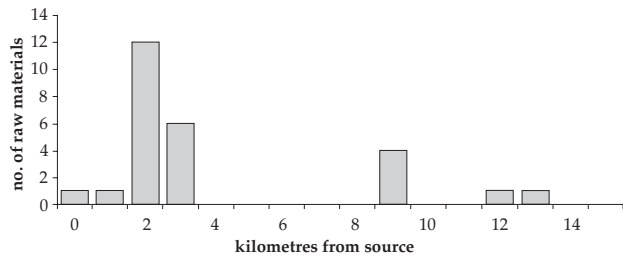
Figure 1. *Transfer distances of raw materials (*n = 26*) at 12 African sites or layers, 1.9–1.6 Ma.*

and objects can be expressed. Arbitrary bi-directional symbols are things (in the context of language this refers to expressions such as utterances and gestures) that represent other things without resembling those things (non-iconic) or pointing to them (non-indexical). The expression of displacement is the ability to refer to actions, objects and ideas beyond the immediate context or beyond the 'here-and-now'. Protolanguage is harder to define, but probably included basic symbolic reference to perceived phenomena and the ability to communicate about them in simple topic-comment strings. Protolanguage need not have syntax, the ability to express displacement or regular context-free symbol use. I argue here that protolanguage possessed long-term stability but limited expressive power and that extensive use of symbols was not common amongst protolanguage speakers.

The model proposes that the distances of raw-material transfers for late Pliocene hominids 2.5–1.9 million years ago suggest they used primate communication, status-based negotiation, and had some planning ability. Raw-material transfer distances for non-modern hominids 1.9–0.2 million years ago show an increase at about 1.0 million years ago, indicating the emergence of a protolanguage, the ability to negotiate face-to-face and to pool information in a local group. The emergence of the protolanguage may have been selected for by a climatic change towards increased aridity. For modern humans, language abilities become visible after 130,000 years ago in Africa, and after 100,000 years ago in Europe. Using the Neanderthals as a case study, and evidence from computer simulations, I show that language evolution was a gradual process with at least three distinctive stages.

Late Pliocene hominids

The oldest stone artefacts currently known come from Gona, Ethiopia and date to 2.5 million years ago

(Semaw 2000). There are 14 hominid sites with stone artefacts in equatorial Africa dating between 2.5 and 1.9 million years ago (Feblot-Augustins 1997, inventories 1 & 2). The distances of raw-material transfer at these sites are either not documented or less than one kilometre.

After 1.9 million years ago the first *Homo habilis* fossils appear in the East African rift valley (Klein 1999). The most significant distinguishing feature of *Homo habilis* is an increase in relative and absolute brain volume (Elton *et al.* 2001). Also dating to about 1.9 million years ago are the oldest examples of raw-material transfers greater than 1 km. During the period 1.9–1.6 million years ago there are data on 26 instances of raw-material transfers from 12 sites or layers at Olduvai Gorge (Tanzania) and Koobi Fora (Kenya) (Feblot-Augustins 1997, inventory 3–4). Most of these transfers were over a distance of three kilometres or less, with a small number of transfers at greater distances to a maximum of 13 km (Fig. 1). Over 95 per cent of artefacts are made on stone collected from a distance of 3 km or less (Feblot-Augustins 1997, inventory 4).

The 13 km distance is a reasonable approximation for the minimum home-range radius of late Pliocene hominids. Individual late Pliocene hominids were probably able to procure raw material directly from 13 km as part of their ranging activity. Whether the hominids moved the raw material in one trip or in a series of small transports is not a crucial point. The significant detail is that the late Pliocene hominids had the cognitive capacity to acquire raw material and hold on to it until they were 13 km from the source. Steele (1996) has predicted hominid home-range sizes from regression equations involving measurements of adult body mass, brain volume, group size and home-range diameter. For a local group of 25 *Homo habilis* individuals, Steele (1996, 249) predicts a maximum home-range radius of 13 km. This independently confirms the reliability of raw-material transfer distance as an indicator of home-range size for late Pliocene hominids.

Primate home range and object transfer data

The suggested home-range size for late Pliocene hominids, is similar to the home-range radius of primates in equivalent environments. Chimpanzees at Mt Assirik (Senegal) occupy an arid environment that is a patchwork of riverine forest, open and closed woodland, scrub and dry and wet grassland (McGrew *et al.* 1981). Pollen, faunal and sedimentation data suggest that Plio-Pleistocene East Africa
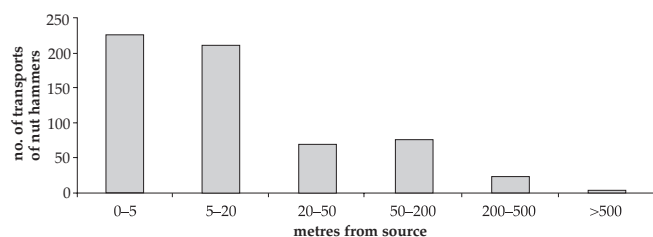
Figure 2. *Distances of 603 transports from 4 years of observations of wild chimpanzees in the Taï National Park (tropical rainforest).*

had an equivalent patchwork environment (Reed 1997; Sikes 1994). The Mt Assirik chimpanzees have a home-range size of 278–333 km², indicating a home-range radius of 10.3 km (Baldwin *et al.* 1982). This is similar to the 13 km minimum home-range radius for late Pliocene hominids suggested by raw-material transfer and anatomical data.

While home-range size may be similar for late Pliocene hominids and chimpanzees, the distances of raw-material transfer are strikingly different. Observations of chimpanzees in the tropical rain forest of Taï National Park (Ivory Coast) show that of 603 transports of stone and wood hammers used for nut cracking, 83.5 per cent ($n = 504$) are over less than 50 m (Fig. 2; Boesch & Boesch 1984). Transport distances of 50–500 m represent 16 per cent ($n = 96$), and distances over 500 m represent 0.5 per cent of all observed transports (Boesch & Boesch 1984). The Taï National Park chimpanzees live in a home range of 27 km², indicating a theoretical radius of 2.9 km (Boesch & Boesch 1984). Assuming 500 m as a maximum raw-material transport distance, chimpanzees moved objects a distance equal to 17 per cent of their home-range radius. On the other hand, archaeological and anatomical evidence suggests that late Pliocene hominids moved objects 100 per cent of their home-range radius.

The difference in distances of raw-material transfer between chimpanzees and late Pliocene hominids may partly be due to ecological differences, but a more significant factor is the increased capacity for planning the use of objects. While a chimpanzee is able to pick up a rock with the intention of using it as a hammer 500 m away, chimpanzees do not demonstrate the capacity to plan for tool use more than 500 m away or more than a few minutes into the future. Late Pliocene hominids, by contrast, were able to pick up a rock with the intention of using it 13 km away, or at least after one day's ranging. This difference in raw-material transfer pro-

vides evidence of cognitive abilities that distinguish late Pliocene hominids from chimpanzees.

Late Pliocene hominids did not have language

Although late Pliocene hominids have a greater capacity for planning than chimpanzees, the distances of raw-material transfer do not suggest that they used language. Raw material transfers indicate a home-range size similar to that of chimpanzees in an equivalent environment to Plio-Pleistocene Africa. Data on dental microanatomy and brain size from late Pliocene hominids suggest a short maturation period and a short life-span similar to those of large primates (Smith & Tompkins 1995). Maturation period, life-span and brain size in primates are correlated with social complexity, measured as a function of group size (Dunbar 1992; 1993; Joffe 1997). The similarity in home-range size and life history between late Pliocene hominids and primates supports the analogy of primate social organization and communication for late Pliocene hominids.

Chimpanzee social organization, while fluid and flexible, is typified by dominant males who lead the movement of groups. Goodall's (1986, 207–30) observations of the ranging patterns of the chimpanzees at Gombe (Tanzania) shows that the movements of social groups (composed of close kin) are controlled by a dominant individual's response to the distribution of food and water, the availability of females in oestrus, the size and movement of neighbouring communities and the presence of predators or other dangers. A similar pattern of behaviour was observed by Tutin *et al.* (1983) at Mt Assirik where chimpanzees formed large, stable, mixed-sex groups for travelling. Although Tutin *et al.* (1983) do not state that the group was led by a dominant individual, Goodall (1986, 409–42) observes that large mixed-sex groups typically have a male dominance hierarchy led by an alpha male. Given the similarities in home-range size and life history, the chimpanzee model of dominant individuals controlling group movement is a reasonable proposition for late Pliocene hominids.

The significance of chimpanzees and late Pliocene hominids sharing this form of social organization is that it implies that they also shared equivalent forms of communication. Chimpanzee communication consists of sounds, postures and facial expressions that they use to influence the behaviour of other individuals. Chimpanzee communication observed in the wild lacks the three crucial qualities of syntax, regular use of symbols and expression of displacement that define human language.

Dominant individuals in chimpanzee communities act on the basis of private information they have acquired through their individual experience of the environment, and public information acquired through a parasitic process of observing the behaviours and activities of conspecifics (Garber 2000, 271–2). The dominant individual does not directly seek information from other individuals, and other individuals do not have the communicative facility to impart information relevant to group movement patterns. The majority of chimpanzee communication occurs between related individuals, with communication between strangers often a long and uncertain process that includes display, fighting and injury (Wrangham 1987, 66–8; Goodall 1986, 331, 488–534). The outcome of these factors is that moving groups of related chimpanzees are led by an individual who negotiates with other individuals through the use of status and relies on the contents of its own brain to make decisions.

According to the primate analogy, the early hominid communication system was one of non-syntactic expressions with limited use of symbols, produced to alter the behaviour of other individuals in the immediate context. Early hominids lacked the 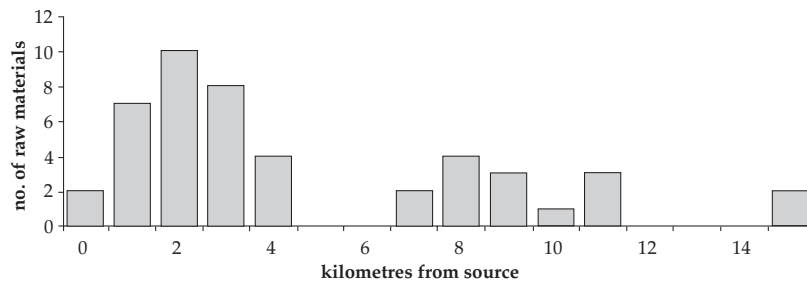ability to express displacement and engaged in the majority of their communicative behaviours within their local group. Early hominids depart from the primate analogy with their increased distances of object movement. The increase in absolute brain size of early hominids after 1.9 Ma may be responsible for the increased capacity for planning suggested by the transfer evidence. Environmental data suggests there were no major selective pressures for large brains or planning ability at 1.9 million years ago (deMenocal 1995), although recent analysis of endocasts suggests that brain expansion began a million years earlier with *Australopithecus* (Falk *et al.* 2000). An earlier increase in brain size may coincide with a shift to arid conditions indicated by marine eolian records and faunal records at 2.8 million years ago (deMenocal 1995). This suggests the possibility of 13 km transfers from a much earlier period than currently available, possibly coincident with the first stone artefacts at 2.5 million years ago.
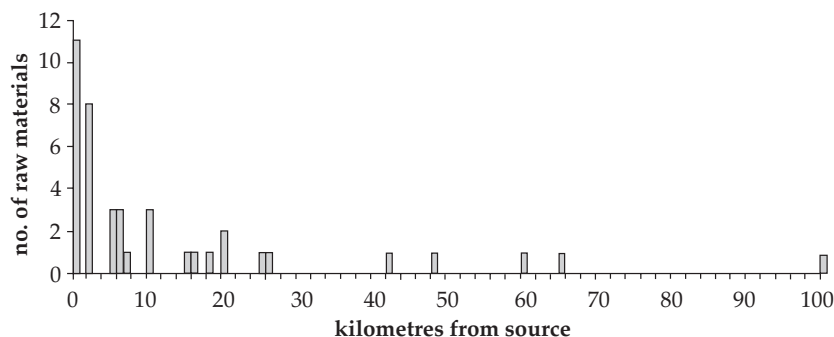
Non-modern hominids

For the period 1.6–1.2 million years ago there are data on 45 raw-material transfers from 14 East African sites or layers (Fig. 3; Feblot-Augustins 1997, inventories 6 & 7). The majority of raw material was acquired from sources near the point of discard: 98 per cent of stone for artefacts was procured from a distance of 4 km or less (Feblot-Augustins 1997, inventories 6 & 7). The maximum distance of raw-material transfer is 15 km, indicating similar strategies of raw-material procurement and landscape use to those of the period 1.9–1.6 million years ago where the maximum distance was 13 km. After 1.2 million years ago, however, maximum transfer distances increase from 15 km to 100 km (Fig. 4). Data on 46 transfers from six East African sites or layers show six occurrences of raw-material transfer between 15 and 100 km (Feblot-Augustins 1997, inventory 10). The significance of this increase is that it demonstrates that after 1.2 million years ago, hominid groups had information about larger areas than earlier hominids. This indicates the appearance of a new ability to exploit larger landscapes for hominids after 1.2 million years ago .

Figure 3. *Transfer distances of raw materials (*n = 45) at 14 African sites or layers, 1.6–1.2 Ma.*

Figure 4. *Transfer distances of raw materials (*n = 41) at 24 African sites or layers, 1.2–0.2 Ma.*

Non-modern hominids used a protolanguage

Anatomical data for non-modern hominids suggest a home-range radius of 17–49 km (Steele 1996, 249); raw-material distances, however, suggest a home-range radius of up to 100 km. It is clear that for non-modern hominids a new variable has appeared that invalidates the anatomical determinism that limited the home-range size of early hominids. Data from the periods 2.5–1.2 and 1.2–0.2 million years ago come from the same areas of equatorial East Africa so there is no change in ecological conditions (from rainforest to savanna, for example) that might otherwise explain the increase in raw-material transfer distances.

I propose that this new variable is the ability to pool information collected by individuals through face-to-face negotiation and the use of a protolanguage. The dominant individual could plan and decide on the movement of the group with the benefit of information on a much larger area than that individual alone could acquire from private and public sources (Fig. 5). Mathematical modelling by Reynolds & Zeigler (1979) shows that without the ability to pool information into a centralized decision maker the maximum region accessible to a group is strongly limited by the information gathering of its individual members. After the appearance of a protolanguage the information collection capacity of individual members is no longer a significant limiting factor, having been replaced by the limitations of social organizational structure, scalar stress and the protolanguage (Reynolds & Zeigler 1979; Johnson 1982).

The exact nature of the protolanguage is not evident from these data and it is not possible to determine if it was analytic (Wray 2000) or synthetic (Bickerton 1981; 1998). Nevertheless, the attributes required for pooling information to increase the effective home range include basic symbolic reference to perceived phenomena and the ability to communicate about them in simple topic-comment strings (Whallon 1989, 437; Bickerton 1981, 268–9). The
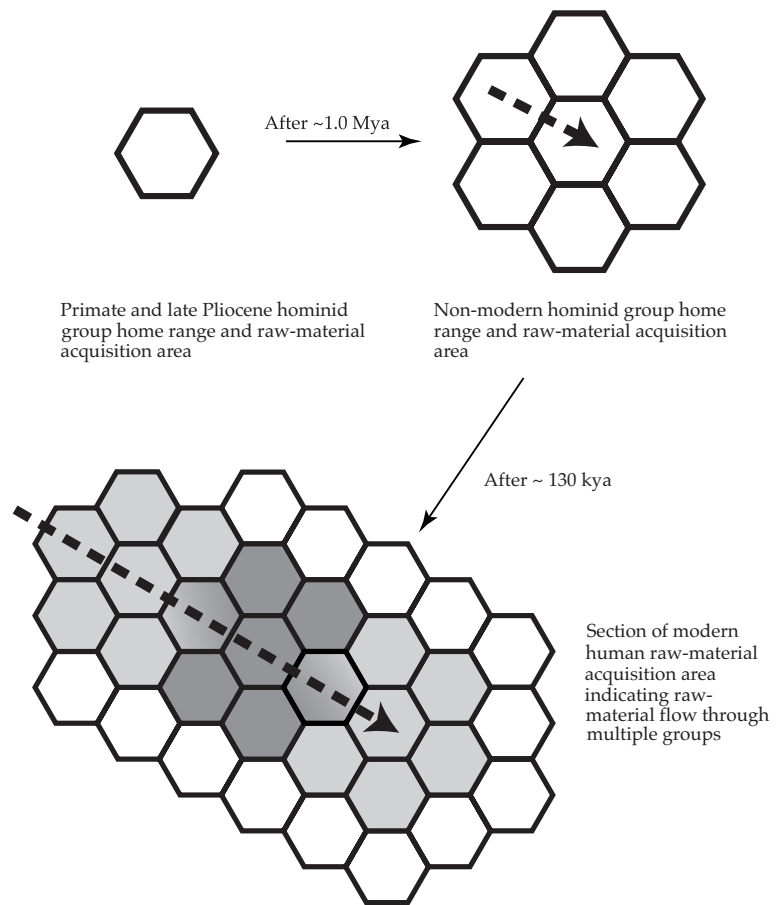

Primate and late Pliocene hominid group home range and raw-material acquisition area

Non-modern hominid group home range and raw-material acquisition area

After ~1.0 Mya

After ~ 130 kya

Section of modern human raw-material acquisition area indicating raw-material flow through multiple groups

Figure 5. *Schematic representation of the three major categories of raw-material transfer distances and associated communication abilities. The single hexagon represents the area about which a dominant primate or late Pliocene hominid possesses information. The group of seven hexagons represents the area about which a non-modern hominid dominant individual possesses information. This is greater than that of the late Pliocene hominid because information collected by (in this case six) other individuals is pooled through the use of a protolanguage. The honeycomb represents exchange networks similar to those ethnographically observed in hunter-gather populations. These networks permit wide area exchange through multiple groups.*

protolanguage need not have syntax, the ability to express displacement or regular context-free symbol use, and is therefore distinct from modern human language. The stability of the 100 km home-range radius for one million years suggests that the protolanguage had long-term stability, while the absence of any evidence of symbolic behaviour in the archaeological record suggests that extensive use of symbols was not common with non-modern hominids and the expressive power of the protolanguage was very limited.

Further evidence of a protolanguage for non-modern hominids

Coinciding with the increase in transfer distances are the first signs of Eurasian colonization. Archaeological sites in Europe such as Atapuerca, Ceprano, Monte Poggiolo and Orce and in West Asia such as Ubeidiya and Gesher Benut Ya'aqov suggest a hominid presence around or just after 1.0 million years ago (Klein 1999, 314–27). The evidence at these sites indicates non-intensive and short-term occupation. Although the first traces of colonization appear at the same time as the increases in raw-material transfer distances, the most persuasive evidence of European colonization by non-modern hominids occurs after 500,000 years ago. After 500,000 years ago there are signs of intensive long-term occupation at European sites such as Boxgrove, Ambrona, Torralba, Cagny-la-Garenne, Fontana Ranuccio, Isernia La Pineta, Karlich G and Miesenheim 1 (Roebroeks 2001).

The delay in the intensive occupation of Europe from the early attempts at 1.0 million until 500,000 years ago is not related to language abilities but probably to the presence of giant hyenas and sabre tooth cats in Europe. Giant hyenas (*Pachycrocuta brevirostris*) and sabre tooth cats (*Megantereon whitei*) are carnivorous predators whose dental anatomy suggests that they were hunters of large animals (Arribas & Palmqvist 1999). The presence of these predators and the carcasses they discarded provide an ecological niche that the first hominid occupants of Europe at 1.0 million years ago were able to exploit without Acheulean technology (Arribas & Palmqvist 1999). After the giant hyenas and sabre tooth cats disappear from the European faunal record at 500,000 years ago, however, a more stable and productive hunting niche opened up for hominids using Acheulean technology (Turner 1990; 1992). Although the human role in faunal assemblages is ambiguous at first, the three 400,000-year-old throwing spears from deposits at Schöningen found in association with hundreds of horse bones, many of them with signs of butchery, provide a compelling case that these hominids occupied the niche of a hunter (Thieme 1997).

The appearance of a protolanguage amongst non-modern hominid groups in Africa coincides with environmental changes that may have generated selective pressure favouring the ability of individuals to expand their group's home-range size. Oxygen isotope evidence of global ice volume and analysis of wind-blown dust sediments from ocean bed cores indicate a shift in African climate variability from 41,000-year glacial cycles to 100,000-year cycles at 1.0 million years ago (deMenocal 1995). Coincident with the change to 100,000-year glacial cycles, the African sediment records suggest a marked increase in glacial amplitude (deMenocal 1995). Further evidence of an increase in cool and dry conditions in Africa at this time comes from the fossil record of African bovidae documenting increased proportions of arid-adapted species nearly 1.0 million years ago (Vrba 1995).

This intensification of aridity may have provided conditions that selected for more complex communication systems. Hurford (1989) and Nowak & Komarova (2001) have used evolutionary game theory to show that arbitrary bi-directional signs will be selected in preference of other schemes over evolutionary time. The results of Hurford's (1989) simulation indicate that the Saussurean strategy of the arbitrary bi-directional sign can become the dominant strategy of communicative behaviour when there are selective advantages for successful communication. Chimpanzees trained or raised by humans appear to demonstrate greater powers of syntactic comprehension and symbol-use than wild chimpanzees, but never greater than that of a two year old child (Savage-Rumbaugh *et al.* 1998). Just as wild chimpanzees demonstrate greater competence in symbol use when trained, so may stressful conditions at around 1.0 million years ago have selected for hominids capable of using symbols to communicate information on resources over a wide area.

Anatomically modern *Homo sapiens*

From about 500,000 to 70,000 years ago the pattern of raw-material transfers in Europe resemble those in Africa after 1.0 million years ago, with the majority of transfers occurring within 15 km of the discard location although some occur up to 80 km away (Fig. 6). The first evidence of raw-material transport beyond the 100–120 km barrier occurs in Africa during the Middle Stone Age (MSA, *c.* 250–40,000 years ago). Songhor, Muguruk, Nasera Rock Shelter, GvJm-16, Mumba Rock Shelter (dated by U-series to 100–130,000 years ago) and Porc Epic are excavated sites containing MSA stone artefact assemblages with artefacts made from obsidian sourced between 140 and 340 km away (Fig. 7; McBrearty & Brooks 2000, 514–15). At GvJm-16, Prospect Farm and Prolonged Drift, the raw material for the majority of stone artefacts comes from local obsidian sources, raising the question why the occupants of the site acquired obsidian indistinguishable in appearance and mechanical properties from distant sources (Merrick *et al.* 1994, 43).

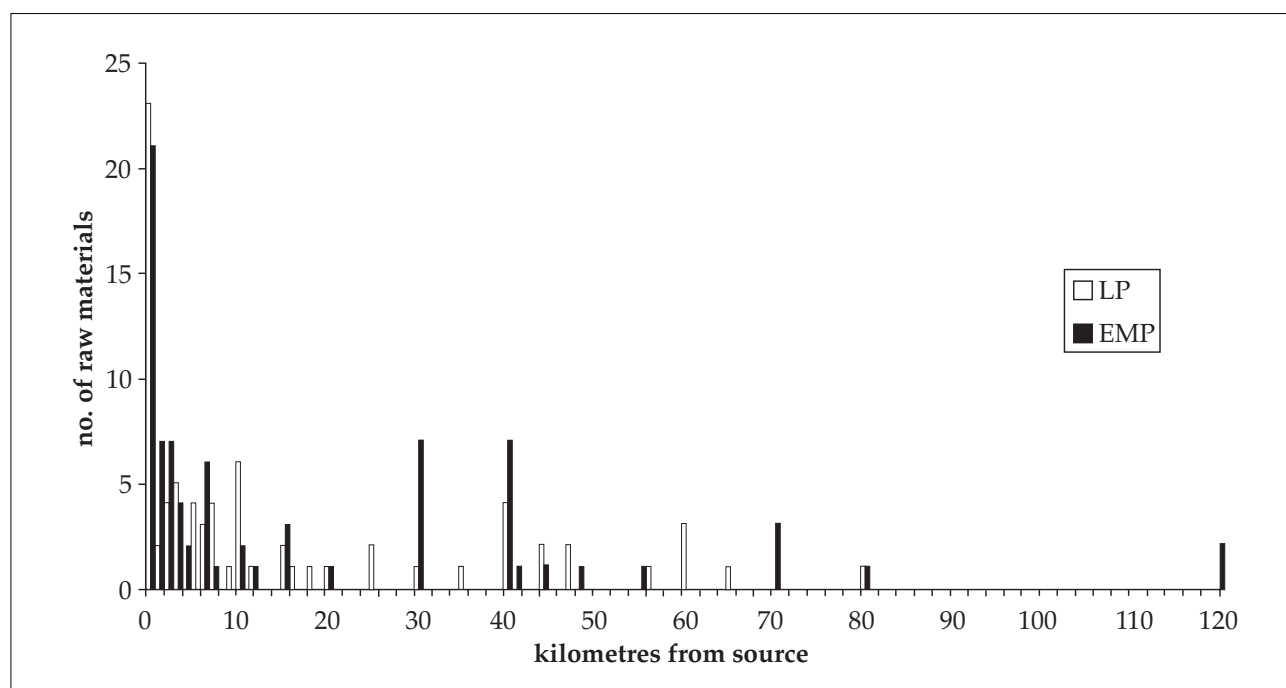Transfers of raw materials over 100–120 km,

Figure 6. *Transfer distances of raw materials at 57 European sites or layers in Europe from Lower Palaeolithic (LP,* n *= 76) and Early Middle Palaeolithic (EMP,* n *= 79) 500–70 ka.*

such as those observed during the African MSA, suggest indirect procurement. A global sample of 70 hunter-gatherer cultures indicates a maximum territory radius of 140 km (mode 15 km, range 3–140 km, mean 32 km, std 24 km) (Kelly 1983; 1995). This maximum figure is only approached by groups in the Arctic regions, such as the Nunamiut and Baffinland Inuit, and the Crow whose mobility is aided by the use of horses (Kelly 1995, 128–9). Raw material sourced to more than 140 km is therefore unlikely to have been procured during the seasonal movements of a group. Raw material from 300 km away is double this distance and implies access to a home-range territory more than four times the maximum ethnographically observed.

Ethnographic data summarized by Feblot-Augustins & Perlès (1992) indicate that although movement of around 100 km might be within the range of deliberate forays by mobile foraging groups, transports of raw material over more than 300 km result from exchange between groups. Studies of the movement of hunter-gatherer peoples and the spatial extents of their alliance networks also indicate exchange networks when distances of around 150–300 km are involved. Ethnographic data on the Aka pygmies of the Central African Republic show that individuals moved distances of 1 to 175 km, with 96 per cent of movement being less than 100 km and

Site name	Location	Distance km	Date ka	Quantity	%
Mumba Rock Shelter	N. Tanzania	320	100–130	7	
Nasera Rock Shelter	N. Tanzania	240	MSA	4	
Muguruk	W. Kenya	185	MSA	2	
Songor	W. Kenya	145	MSA	1	
Porc Epic	Ethiopia	140	MSA		6
GvJm-16	Kenya	105	early MSA		2
Prospect Farm	N. Tanzania	75	>120	few	
Prolonged Drift	N. Tanzania	45	MSA		90

Figure 7. *Long-distance raw-material transfer in the African Middle Stone Age.*

half less than 50 km (Hewlett *et al.* 1986). It is highly unlikely that Aka individuals would transfer an object a linear distance of 300 km in the course of their habitual activities. Wobst's (1976) study of mating networks amongst recent hunter-gatherers indicates a maximum distance of 300 km between the most distant local groups involved in closed-system marriage networks. He predicts that beyond 300 km it is maladaptive for groups to engage in food sharing, joint ritual and exchange of sufficient intensity to maintain mate-exchange relations (Wobst 1976, 52).

In light of the ethnographic data, a probable explanation for raw materials moved over 140–300 km is that they moved through networks of exchange involving neighbouring groups. The five African MSA sites with evidence of raw-material transfer distances of 140–340 km therefore suggest the existence of exchange networks (Merrick *et al.* 1994, 43).

Exchange networks and language

Participating in exchange networks requires the specific cognitive and linguistic abilities that define modern humans. Primates do not possess abilities that allow them to form multi-group exchange networks. Primate social interaction with strangers is typified by the uncertainty of the outcome, which may be injury or death. A second feature that prevents primates from operating exchange networks is their limited capacity for exchange. Primates demonstrate the ability for only indirect exchange of goods involving immediate reciprocity (Paquette 1992). For hominids to operate in an exchange network, they need to avoid the uncertain outcomes primates have meeting strangers, and they need to be capable of direct exchange with delayed reciprocity.

The ability to express symbolic categorizations of social systems allows individuals to identify and interact with unrelated individuals in terms of symbolic categories rather than as unique individuals. This allows for relationships based on mutual rights and obligations rather than the histories of interpersonal relations that require renegotiation at each encounter (Whallon 1989, 438). An example of this is the use of biological kin categories for unrelated or distantly related individuals in hunter-gatherer and other modern human groups. Expression of displacement (beyond the here-and-now) allows individuals to negotiate delayed reciprocity as well as reference to kin relations that are not biologically-based and are specific to times and places (such as marriage relations) (Whallon 1989, 439). Syntax is a fundamental requirement, allowing ideas to be expressed in hierarchical sequences and reference to be made to multiple subjects and objects, as is required for the expression of multiple levels of intentionality and in exchange negotiations.

Further evidence of language during the African Middle Stone Age

The archaeological record of the African MSA has other forms of evidence that are congruent with language-using hominids. This includes the appearance of regional diversity in the appearance of functionally equivalent stone projectile points throughout Africa during the MSA (McBrearty & Brooks 2000, 497–500). This stylistic diversity suggests the emergence of bounded ethnic groups within which projectile points are exchanged, similar to exchange networks known from the ethnographic record. Increased planning-depth, economic specialization and

resource scheduling are modern human behaviours that require language-mediated organization. Faunal remains from MSA layers at Klasies River Mouth, ≠Gi and Die Kelders have mortuary profiles suggesting species-selection and seasonal activity, as well as skeletal element representations and cutmarks consistent with hunting rather than scavenging (McBrearty & Brooks 2000, 506–10). At Katanda (Democratic Republic of Congo) there are barbed bone points and an assemblage of large adult catfish bones overlaid by sands dated by TL to >90,000 years ago (Brooks *et al.* 1995; Yellen *et al.* 1995).

There is also evidence of symbolic behaviour at African sites during the MSA. Body ornaments are known from at least three African sites dating from 130,000 to 40,000 years ago. These include a perforated shell from Oued Djebanna (Algeria), four deliberately-drilled quartzite flakes from Debenath (Nigeria) and a bone pendant from Grotte Zouhra (Morocco) (McBrearty & Brooks 2000, 521). A piece of ochre with multiple incised hatchings at Blombos (South Africa) underlies sterile dune sands dated by OSL to 73,000 years ago (Henshilwood & Sealy 1997). At Apollo 11 (Namibia) incised ostrich egg fragments have been dated by AAR to >83,000 years ago (Miller *et al.* 1999).

The evidence of modern human behaviour found at African MSA sites does not appear in Europe until the transition from the Middle to Upper Palaeolithic around 40,000 years ago (Mellars & Stringer 1989). Data on raw-material transfers from Europe provide evidence of modern language abilities also at around this time. The first evidence of transfers over distances greater than 140 km occur in central Europe during the Late Middle Palaeolithic (100–45,000 years ago) and Early Upper Palaeolithic (45–30,000 years ago) (Fig. 8). From a sample of 24 sites or layers and 82 occurrences of transfers for the Later Middle Palaeolithic in central Europe there are seven occurrences of raw-material transfers between 140 km and 300 km (Feblot-Augustins 1997, inventory 30). During the Early Upper Palaeolithic in central Europe (including transitional industries such as the Szeletian and Jerzmanowician) there are 55 sites or layers and 223 occurrences of transfers, with 29 occurrences between 140 and 420 km (Feblot-Augustins 1997, inventories 60, 62).

Evidence of transfer distances in the range 140–400 km do not appear at west European sites until the Aurignacian period (35–28,000 years ago), and the material transferred is not stone but marine and fossil shell (Roebroeks *et al.* 1988). In the later Upper Palaeolithic (21–11,000 years ago) marine and fossil
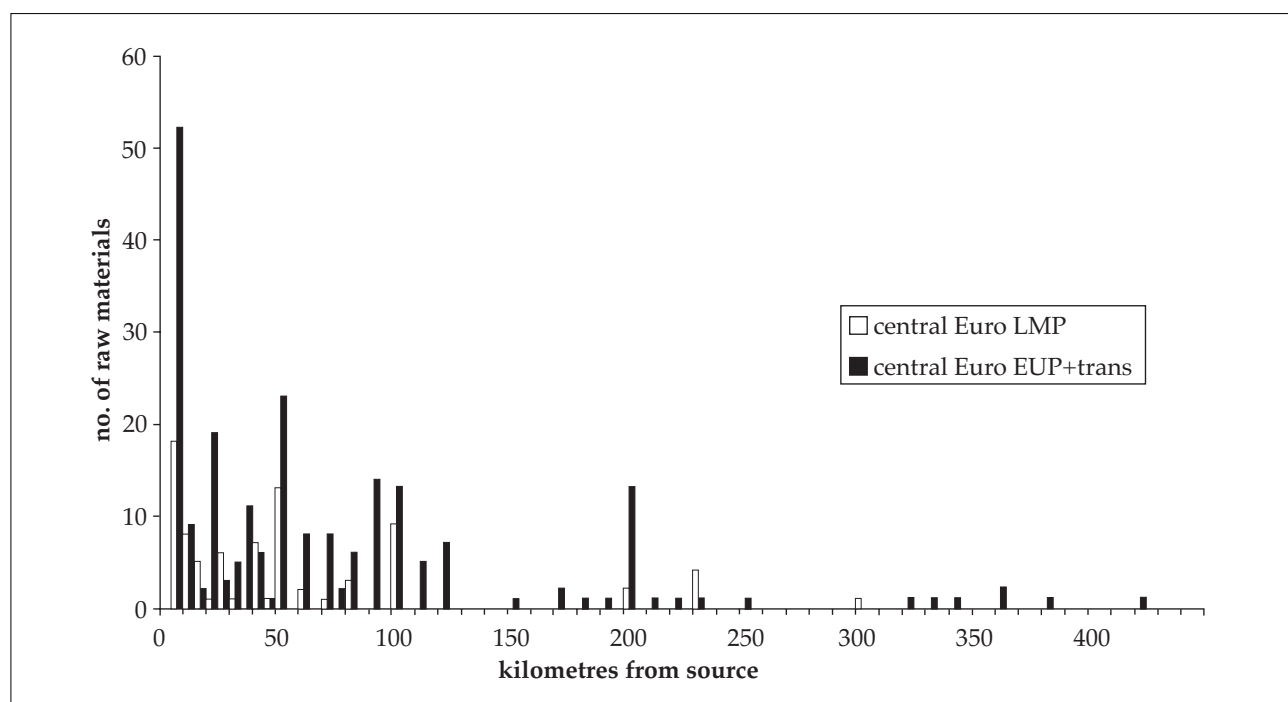
Figure 8. *Transfer distances of raw materials during the European Late Middle Palaeolithic (LMP, 24 sites or layers,* n *= 82) and Early Upper Palaeolithic including transitional industries (EUP, 55 sites or layers,* n *= 233) in central Europe.*

shells were transported over 800 km (Feblot-Augustins 1997, figs. 81–4). These very long-distance transfers suggest the presence of open networks where the importance of objects is transformed from the functional to the social and ritual realms as they are circulated through the networks (Feblot-Augustins & Perlès 1992). Further developments related to language include the appearance of the first European cave paintings and portable art after 30,000 years ago, in particular the highly-stylized and widely-distributed Venus figurines (28–21,000 years ago) (Klein 1999, 545–53). The production of art and the very long-distance transfers suggest use of symbols, which is a crucial feature of language.

Gradual or catastrophic emergence of language? Neanderthals as a case study

Previous authors have suggested that the emergence of language was a catastrophic process. Mellars (1996a,b) argues that it is coincident with the behavioural transformation that he refers to as the 'Upper Palaeolithic Revolution'. Bickerton (1998, 354) suggests that the transition from protolanguage to language was a 'cognitive explosion' that occurred after the emergence of modern humans in Africa. Noble & Davidson (1996, 8) argue in favour of an 'all-or-none' approach to symbol-based communication and reject the notion of a protolanguage. Contrary to the above scenarios, I propose that a more gradual evolution of language can be supported. While some evidence for the appearance of language in Europe suggests it arrived with hominids from Africa, other evidence indicates that the transition from protolanguage to language was occurring in Europe within non-modern hominid populations. Neanderthal groups occupied Europe and west Asia from 300,000 to 35,000 years ago, and archaeological evidence suggests that their linguistic abilities were intermediate between earlier non-modern hominid species such as *Homo erectus* and modern humans. As Neanderthal populations span the critical period of language emergence in Europe and there is a relatively large amount of data on them, they make a good case for the study of gradual versus catastrophic language emergence.

There is ambiguous evidence for some symbolic capacity amongst Neanderthal populations. Ochre fragments with signs of scraping have been found in a number of Neanderthal sites in southwest France, although there is no indication of how they were used (Mellars 1996a, 20). Over a dozen Neanderthal burials have been recorded in France and West Asia, although there is much contention about

the role of taphonomic and site-formation processes (Gargett 1989; 1999). Most archaeologists agree that even if Neanderthals did bury their dead, the absence of convincing grave goods in the burials, and symbolic artefacts generally, indicates that ceremonial and symbolic behaviour was not widespread (Chase & Dibble 1987). A number of sites have inscribed, perforated or worked bone pieces associated with Neanderthals although there is much ambiguity concerning the role of intentionality and symbolism in their production (Villa & d'Errico 2001; Hayden 1993; Chase & Dibble 1987; 1992). Sites in western Europe, such as Arcy-Sur-Cur and St Cesaire, and in central Europe, such as Vindija and Velika Pecina, show associations of Neanderthals with Upper Palaeolithic technologies that are variously argued to result from imitation, acculturation or trading with modern human populations, or to stratigraphic mixing (Karavanic & Smith 1998; Hublin *et al.* 1996, 226; Lévêque *et al.* 1993). To sum up the archaeological evidence, Neanderthals were probably closer to modern humans that other non-modern hominid species, although they never demonstrated the full panoply of modern behaviours observed in the African MSA and the European Upper Palaeolithic.

The raw-material transfer data currently does not have the resolution to distinguish between material moved by the last Neanderthals or the earliest modern humans in central Europe during the Middle–Upper Palaeolithic transition. The hominids associated with the central European transitional industries are currently uncertain (Bolus & Conard 2001). However, the transitional industries in western Europe (e.g. Châtelperronian) have transfer patterns resembling non-modern hominids with distances not exceeding 70 km (Feblot-Augustins 1997, inventory 32). The problem here is that transfer data suggests the Neanderthals used a proto-language similar to other non-modern hominids, whereas other archaeological evidence suggests a level of cultural and cognitive complexity greater than previous non-modern hominids. What sort of language lies between the protolanguage of non-modern hominids and modern human language?

Computer simulations and biological evidence

A suggestion can be found in computer simulations of the evolution of language. These show that complex structured languages spontaneously emerge in populations of learners even though the population has no common signalling system and is not subject to any biological change (Kirby 2000). Many authors have argued that syntax is a result of natural selection (Pinker & Bloom 1990; Newmeyer 1991; Bickerton 1998). Recent work, however, suggests that language itself is a complex adaptive system that is 'more likely to have adapted itself to its human hosts that the other way round' (Christiansen 1994, 125). Kirby's (2000, 305) simulation takes individuals that learn observationally (rather than through explicit reinforcement), a gradual turnover of members of the population over time (ensuring true transmission of knowledge through the system), no selection of individuals (death is random to ensure that linguistic success is unrelated to adaptive success) and an initial non-linguistic population (so that any biases that emerge in the simulation are a product of the model). Communication begins because of random invention and noise events where an individual produces a randomly-constructed string of symbols (phonemes or words for example) with a randomly-chosen meaning.

Although the results of Kirby's (2000) simulation are the product of an explicitly non-biological process, they provide an attractive model for the emergence of syntax in human populations. The results of the simulation show three stages in the evolution of syntax (Fig. 9). Stage One is a long and stable period where individuals are able to express a small number of the total meanings possible in the simulation using a small grammar. Grammars during this first stage are not sets of rules but vocabulary lists with meanings expressed as arbitrary unanalyzed strings of symbols. Kirby (2000, 317) describes Stage One as a communication system that is 'nothing more than an inventory of calls expressing unanalyzed meanings' with 'an impoverished, idiosyncratic vocabulary of one-word utterances'. The lack of syntax and the stability of the communication system in Stage One is analogous to the protolanguage of non-modern hominids that emerged around 1.0 million years ago and lasted until about 130,000 years ago.

Stage Two is a period of unstable and unpredictable changes. The size of the grammar and the number of meanings expressed increases dramatically, but fluctuates wildly. An important change from Stage One is that the number of meanings becomes greater than the number of rules in the grammar. Kirby (2000, 317) describes the language of Stage Two as 'brittle . . . and liable to break and lose its expressive power suddenly'. He notes that the grammars at this stage are more complex than Stage One and that 'the details of what is going on in the lan-

guage of the population at this stage are hard to figure out' (Kirby 2000, 314). I believe that this stage is a reasonable approximation of Neanderthal linguistic abilities, with their behavioural capacity somewhere between earlier non-modern hominids and modern humans, but raw-material transfers firmly in the range of earlier non-modern hominids. The type of language emerging at Stage Two of the simulation may have permitted more complex social organization and behaviours within local kin groups, but it lacked the stability and flexibility to maintain multi-group networks over large areas and long periods. This lack of stability and flexibility may explain why Neanderthal raw-material transfer distances are similar to those of earlier non-modern hominids, and why Neanderthals did not develop cultural behaviours that became persistent and widespread.

Figure 9. *Kirby's simulation of the non-biological evolution of syntax. (From Kirby 2000.)*

Following an abrupt transition, the third stage of the simulation appears with a sudden increase in the number of meanings that can be produced, to the maximum value allowed by the simulation and a drop in the size of the grammars (Kirby 2000, 314). There is now a regular correspondence between meanings and expressions and the individual's grammars are compositional and have syntactic categories for nouns and verbs. This stage constitutes a simple system with long-term stability and great expressive power. The third stage is an ideal analogue for the emergence of modern language, with syntax and massive expressive power controlled by a Universal Grammar consisting of a few general rules.

Although it seems likely that Neanderthals were operating with a Stage Two language, whether or not they made it to Stage Three may never be known. Non-biological linguistic evolution and biological and cultural evolution influence each other in ways that are difficult to predict (Kirby & Hurford 1997; 2001). Mathematical models of language evolution show that once language abilities appear in a population and certain demographic and information thresholds are reached, evolutionary processes select for language in favour of other communication systems (Nowak & Krakauer 1999; Nowak *et al.* 2001). Biological and cultural differences between Neander-
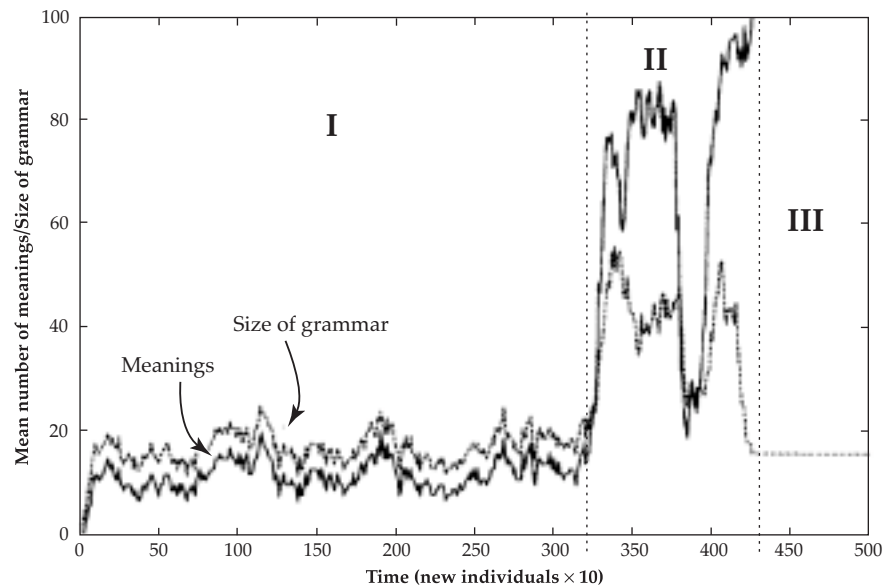
thals and modern humans probably produced different patterns of linguistic evolution that resulted in modern humans arriving in Europe with language and replacing the less loquacious Neanderthals.

While Kirby's simulations suggest a gradual process of language evolution, and help us to understand the abilities of the Neanderthals, further simulations by Tonkes & Wiles (2002) reveal interesting details relating to the length of the learning period and the population size. Their simulations show that populations converge on languages regardless of their size, but that the time taken to converge is greater in larger populations. In larger populations, the communicative error rate is higher and the possibility of two or more different languages emerging is higher, taking greater time for one language to dominate and the error rate to stabilize at a tolerable level. This suggests that a relatively small population size was optimal for the emergence of language and exchange networks.

Genetic evidence, such as segregating *Alu* insertions, mitochondrial mismatch distributions, X- and Y-chromosome microsatellite loci and protein polymorphism, indicate a suite of coalescent events between 180,000 and 120,000 years ago (Goldstein *et al.* 1995; Hammer *et al.* 1997; Harding *et al.* 1997; Harpending *et al.* 1993; Harris & Hey 1999; Nei & Roychoudhury 1974; Stoneking *et al.* 1997). Harpending *et al.* (1998) and Reich & Goldstein (1998) interpret these coalescences as the result of a population bottleneck roughly coincident with a glacial

phase peaking around 130,000 years ago (Lahr & Foley 1998, 163–4). In light of the simulations of Tonkes & Wiles (2002) the population contraction at 130,000 years ago is an optimum condition for the emergence of language, allowing its spread to be rapid and minimizing the possibility of maladaptive and prolonged communicative errors and multiple mutually unintelligible languages.

These simulations also show that longer learning periods vastly reduce the communication error rate in a population. Dean *et al.* (2001) analyzed daily incremental markings in enamel to calculate rates of enamel formation in 13 fossil hominid specimens dating between 4.0 million and 120,000 years ago. They found that the slow trajectory of enamel growth during prolonged maturation typical of modern humans appeared relatively late in hominid evolution, at around 120,000 years ago (Dean *et al.* 2001). This evolution of a longer maturation and learning period (also called the critical period) may have been the final anatomical precondition for the emergence of language following the lowered larynx, an appropriately shaped hyoid bone, muscular control of the tongue and chest and an adequate angle of basicranial flexion.

Conclusion

Distances of raw-material transfer by Pleistocene hominids show three important stages that relate to language ability. The first stage begins at about 1.9 million years ago with a maximum raw-material transfer distance of 13 km and shows early hominids to have had a capacity for planning greater than chimpanzees. The second stage occurs at about 1.0 million years ago when the maximum transfer distance increases to 100 km, suggesting the presence of a protolanguage that facilitates pooling of information. This enabled African non-modern hominid groups to exploit much larger territories than before. The protolanguage allows basic topic-comment expressions and symbolic reference, and simulations suggest that it was analytic rather than synthetic (cf. Wray 2000). The protolanguage may have been selected for during the intensified aridity of the African climate 1.0 million years ago.

The third stage is marked by maximum transfer distances of >300 km, first appearing in Africa 130,000 years ago and after 100,000 years ago in Europe. This third stage represents the emergence of exchange networks that require a communication system allowing expression of displacement and symbolic categorization of social systems, namely human language. At around 130,000 years ago biological evidence suggests small population sizes and the appearance of a delayed maturation in human life history, features that computer simulations indicate are optimum conditions for the evolution of language.

I have argued using archaeological evidence and computer simulations that language evolution was a gradual process. A computer simulation produced by Kirby (2000) shows that non-biological evolution can transform a protolanguage into a language. I propose that the intermediate stage of languages (Kirby's Stage Two) that are highly unstable and highly variable in their complexity and expressive power may explain the paradox of the Neanderthals who may have been capable of some near-modern behaviours but did not use exchange networks. A significant detail of Kirby's simulations is the importance of non-biological linguistic evolution. This introduces a third factor that I have attempted to include in my model, along with biological and cultural evolution. Given the lack of genetic change or speciation events in hominid populations during the MSA, it is possible that linguistic and cultural evolution were the main forces behind the emergence of language.

Although in early stages of development, the narrative presented here has the advantage over previous ones of being capable of testing through the collection of additional data on raw-material transfers in Africa, Europe and Asia. If the timing and patterning of the crucial thresholds of 13 km, 100 km and 300 km are shown to be unreliable and fail to be confirmed in future research (which should consider data from China, central Asia and southeast Asia) then the narrative proposed here can be rearranged or rejected altogether. Alternative methods for calculating home-range sizes with raw-material transfer distances could also be used to test this model, such as minimum convex polygons and the adaptive kernel methods (Gamble & Steele 1999).

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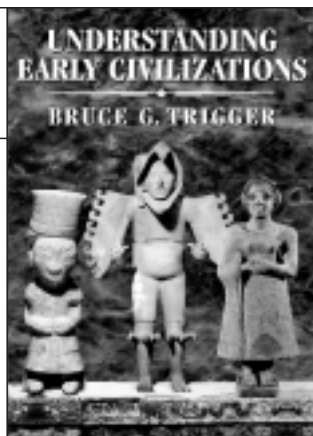
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Ben Marwick has studied archaeology at the University of Michigan and the University of Western Australia where he recently completed a MA thesis in Australian Aboriginal archaeology. His research interests include the evolution of modern humans and Australian Aboriginal archaeology. Ben is currently a tutor at the University of Western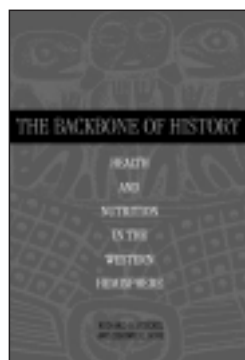 Australia Centre for Archaeology.