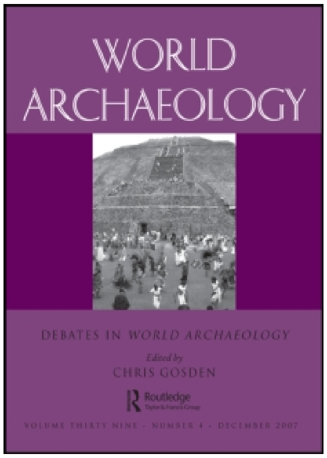

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Neanderthal extinction and modern human behaviour: the role of climate change and clothing

Ian Gilligan

Abstract

Thermal considerations can help resolve two of the most challenging problems in later Palaeolithic archaeology – the demise of Neanderthals and the emergence of modern human behaviour. Both can be viewed as reflecting interactions between biological and behavioural cold adaptations, in the context of extreme climatic fluctuations during the Upper Pleistocene. Recent studies draw attention to the special difficulties these conditions posed for humans but few give sufficient regard to the need for adequate pre-adaptations, namely technologies for manufacturing complex clothing assemblages. It is argued here that pre-existing biological cold adaptations delayed the development of such technological capacities among Neanderthals, resulting ultimately in their extinction. In contrast, the greater biological vulnerability of fully modern humans promoted a precocious appearance of behavioural adaptations among some (though not all) groups, visible in the various archaeological markers of modern human behaviour.

Keywords

Clothing; cold adaptations; Neanderthals; modern human behaviour.

Two big problems

This exploratory paper is prompted by a recent review in this journal of Neanderthal survival skills (White 2006) and the findings of the Stage 3 Project relating to Neanderthal extinction (van Andel and Davies 2003). The emphasis is on ideas rather than data. The ideas relate to how the development of clothing for thermal reasons can be rendered visible archaeologically and how this may illuminate two of the most contentious problems in Palaeolithic archaeology – Neanderthal extinction and the emergence of modern human

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behaviour. The focus is on fundamentals and patterns in the big picture, rather than on variability among individual pixels (the data) that compose the picture. In looking at large-scale trends and relationships between different data domains, the aim is not to demonstrate the validity of this thermal interpretation so much as to illustrate its explanatory potential.

Neanderthal extinction

Despite intense research and debate, the question of why Neanderthals disappeared remains essentially unresolved (Straus 2005). Moreover, the debate has raised concerns that dubious preconceptions have biased our interpretations of their capacities compared to those of fully modern humans. As Speth (2004) points out, the posited reasons for their demise are based on absence of evidence and inferred inadequacies on their part. In fact, the available evidence indicates that the adaptive strategies of Neanderthals (and of their immediate forebears) were successful for a very long period, encompassing a number of glacial/interglacial cycles. Neither do existing data provide much support for the long-cherished idea that Neanderthals were pushed to extinction by competition from fully modern humans.

The most extensive recent examination of Neanderthal extinction is the Stage 3 Project (van Andel and Davies 2003). Its findings indicate that the sudden, extreme environmental fluctuations late in MIS3 somehow brought Neanderthals unstuck. Also, Neanderthals were cold-adapted but only up to a point – they favoured mild cold and avoided more severe cold. However, based on physiological considerations and on their own wind chill estimates, these researchers were reluctant to blame the cold itself for the extinction of Neanderthals.

Modern human behaviour

The concept of modern human behaviour has problems of its own, not least of which is that its more readily identifiable archaeological markers (notably blade-based lithics and bone technologies) have become less reliable (e.g. Bar-Yosef 2002). Instead there has been a shift towards more ambiguous markers such as the development of novel cognitive, linguistic or symbolic capacities – for which the archaeological evidence is weak (e.g. Wolpoff et al. 2004: 535–8). Furthermore, it has yet to be shown that modern human behaviour bestowed any tangible superiority in terms, for instance, of food procurement strategies – at least not during the critical 50,000 to 30,000 BP period – or why the inferred lack of such capacities would disadvantage Neanderthals at that time (e.g. Adler et al. 2006). As the Stage 3 Project shows, the archaeological picture is consistent with Neanderthals retreating southwards into warmer refugia and dwindling in numbers, then more or less disappearing. Fully modern humans equipped with modern human behaviour moved into parts of Europe that had already been essentially vacated by Neanderthals, with stratigraphic gaps (often of a few millennia or more) at sites where the changeover is well attested. Indeed, Neanderthals lasted in southern Iberia until around 30,000 BP, long after fully modern humans had moved into northern Spain by around 40,000 BP (e.g. Hublin et al. 1995).

Though discounted by the Stage 3 Project, cold adaptations may have played a direct role, mainly in terms of the development of clothing for thermal reasons. This argument circumvents many of the difficulties inherent in current approaches, and offers comparatively pragmatic explanations for both Neanderthal extinction and the emergence of modern human behaviour.

Origin of clothing

Before proceeding further, an underlying assertion in this thermal approach must be made explicit. This is that clothing has its prehistoric origins in protection from cold. The argument in favour of thermal origins is covered elsewhere (Gilligan in press a; Gilligan submitted). In essence, a thermal model is the most logical and parsimonious, and alone is consistent with all available lines of evidence. Additionally, it opens up promising possibilities (using physiological and palaeoenvironmental sciences) for rendering Palaeolithic clothing more visible and for re-interpreting major trends in prehistory.

Another area to be summarized briefly at this point is the thermal physiology of human cold tolerance and clothing. This forms the basis for making a distinction between 'simple' and 'complex' clothing, which has archaeological ramifications.

Thermal physiology and clothing

The principles and experimental findings relating to human responses to varying thermal conditions (e.g. Jessen 2001; Parsons 2003: 293–325) can be summarized only briefly here. In terms of physiological danger, the wind chill temperature (Quayle and Steadman 1998) is a more realistic measure of the cold exposure risks than air temperature alone. Modern humans can become acclimatized to cold, but only down to a 'critical level' (Hensel 1981: 220), below which hypothermia begins within hours and can lead rapidly to death, literally overnight.

Clothing physiology

The thermal insulating properties of clothing are detailed in studies of clothing physiology (e.g. Siple 1945; Burton and Edholm 1955: 58; Hensel 1981). Clothing functions as thermal insulation by trapping air close to the skin surface, reducing the thermal gradient between the body and the external environment. The thermal resistance of clothing is indicated by the 'clo' unit (Gagge et al. 1941: 429); generally, each layer adds nearly 1 clo (Sloan 1979: 17).

The crucial point to be made is the principle of *thresholds*. The various biological defences can cope across quite a wide range of temperatures, and clothing requirements (if any) may vary only marginally. Beyond a certain point, however, a further small fall in temperature can create a situation where the need for additional protection soon becomes critical for survival. Discomfort escalates rapidly into danger, and the suddenness with which this occurs can be deceptive.

Simple vs. *complex clothing*

A distinction is drawn here between 'simple' and 'complex' clothing (Table 1). The distinction is based on physiological principles but, as shown below, it has important archaeological implications. The physiological distinction arises from two aspects that largely determine the thermal effectiveness of clothing: first, whether a garment is properly 'fitted', i.e. shaped to fit closely around the body, including the limbs, as opposed to being loosely draped over the body. The second aspect is the number of layers, with multiple layers requiring that at least the inner layer(s) are fitted. Draped, single-layer clothing can provide only limited protection, up to around 1–2 clo, whereas fitted, multi-layered clothing assemblages can provide up to 4–5 clo, sufficient for survival in polar and sub-polar environments. The former may be termed 'simple' clothing, and the latter 'complex'. Unlike simple clothing, the regular use of complex clothing has non-thermal consequences and, for various reasons, its use tends to become habitual.

Pleistocene clothing

The fact that there are no surviving physical remains of clothing from the Pleistocene is a problem, but not an insurmountable one – many aspects of past human behaviour have left no direct, tangible evidence but are nonetheless of interest to prehistorians. Certain clothing-related items survive such as buttons and eyed needles and also a few artistic depictions, corresponding mainly to the use of complex clothing in the LGM (e.g. Bader and Bader 2000: 29). The thermal model outlined here not only offers the prospect of specifying when and where early humans began to need clothes, but it also becomes

Table 1 Features distinguishing simple and complex clothes

	Simple clothes	*Complex clothes*
Structure		
Number of layers	1	>1
Fitted (or 'tailored')	No	Yes
Thermal physiology		
Level of protection	1–2 clo	2–5 clo
Technology (Palaeolithic)		
Scraping implements	Yes	Yes
Piercing implements	No (generally)	Yes
Cutting implements	No	Yes
Technological mode	3	4
Repercussions		
Impairs cold tolerance	No	Yes
Acquires decorative role	No	Yes
Acquires social functions	No	Yes
Promotes modesty/shame	No	Yes
Becomes habitual	No	Yes

feasible to stipulate environmental conditions that would favour the use of simple clothing and, in particular, promote a transition from simple to complex clothing. Pleistocene clothing may be rendered more visible by combining two strategies:

1. Given its likely thermal origins, physiological and palaeoenvironmental evidence can be utilized to determine minimum clothing requirements.
2. Technological prerequisites for manufacturing the necessary kind of clothing (simple or complex) may already be visible in the archaeological record, and their development and distributions in place and time should correspond with predictions derived from 1.

It is this second strategy that can open up new ways of interpreting major technological trends and transitions in prehistory (e.g., Gilligan in press b). In other words, the Pleistocene archaeological record probably contains considerably more evidence for clothing than beads, buttons and eyed needles, as Hayden (1990) and others (e.g. Soffer et al. 1998) have intimated.

Archaeological signatures of clothing

Simple and complex clothing have different technological correlates. Simple garments made from animal hides require basic skin-preparation techniques, mainly cleaning and scraping, which can be achieved with scraper tools of various descriptions. Complex garments demand that the skins be carefully shaped by cutting, especially for the separate rectangular pieces that form cylinders to cover the limbs, and these need to be joined together in some way, usually by sewing. Where multiple layers are used, the inner garments must be carefully prepared, with finer cutting and sewing to achieve the necessary close fit. Complex clothes, in other words, tend to be associated with more specialized scraping, cutting and piercing implements. The advent of laminar or Mode 4 technologies (Clark 1977) signified a greater emphasis on cutting and piercing activities (blade tools being ideal if cutting edge is a priority, and similarly bone points for piercing hides), hence a greater capacity to manufacture complex clothing. In a Pleistocene context, humans with Mode 4 technocomplexes were better placed to manufacture complex clothing, while those without the technological capacity to manufacture such clothing were restricted in terms of their potential environmental ranges.

Neanderthals and clothing

It is now widely acknowledged that the body form of Neanderthals indicates they were biologically cold-adapted. However, as the Stage 3 Project showed, this provided them with only limited protection. Whether they had a thicker covering of body hair may never be known, but this would have added at most only another 1 clo or so of insulation. They are also likely to have developed maximal – and possibly, for hominins, unusual – physiological cold defences (e.g. Steegmann et al. 2002). Nonetheless, given the likely minimum winter temperatures to which they were exposed, they would have needed additional portable protection to survive when and where they did (White 2006: 558). The required level of such protection corresponds broadly to simple clothing, i.e. single-layer, draped garments, and the archaeological evidence is consistent with an absence of complex clothing (e.g. Kuhn and Stiner 2006: 958). The recent work of Trinkaus (2005) suggests a similar situation for footwear, with their pedal morphology indicating that, unlike among fully modern humans in late Pleistocene Europe, the use of shoes among Neanderthals was limited. Indeed, the cold-adapted Neanderthal body shape itself suggests the use of only simple clothing, as regular use of complex garments would result in a consistently warmer microenvironment for the body and hence a less cold-adapted physique. The heavier pelts from some animal species would provide more than 1–2 clo protection (White 2006: 559) even as single-layered, draped garments, since the clo unit is based on lighter modern garments made from woven textiles – although wind penetration would still expose Neanderthals to risk at more extreme wind chill levels. The technological prerequisites for Neanderthal clothing were those of Mode 3, i.e. scrapers and also basic boring implements to pierce holes in the hides so they could be held in place with strings or cords. Their Mousterian technocomplexes, comprising techniques for reliably generating well-formed scraper tools, were well suited to the manufacture of simple clothing.

The northern limit

One intriguing feature of the archaeological record for Neanderthals is that there was a clear geographical limit to their occupation of Ice Age Europe (Fig. 1), and the most northerly sites date to milder climatic phases (Hublin 1998: 305). No confirmed Neanderthal sites are found north of approximately latitude 55°N, and the boundary

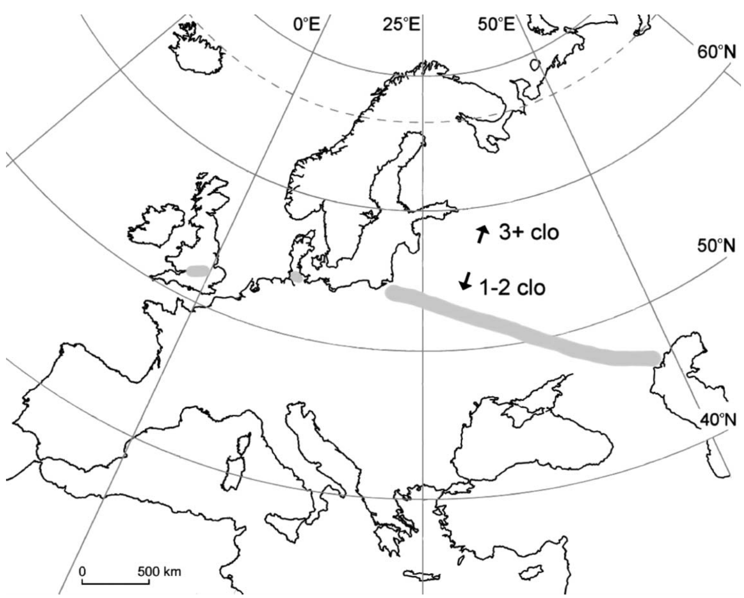

Figure 1 Map of western Eurasia showing the approximate limit to Neanderthal penetration of colder regions requiring 3+ clo of insulation (and hence complex clothing).

retreats further south in continental zones where winter minimums were lower. Yet, as the subsequent expansion of fully modern humans makes clear, colder regions unoccupied by Neanderthals were often rich in resources, and, in terms of extracting food, should have been readily exploitable with Mousterian toolkits. The most plausible explanation is simply that, thermally, the Neanderthals' northern geographical limit marks the limit of their adaptation to cold.

MIS3 cold spikes and wind chill

If the Neanderthals' successful adaptation to moderate cold allowed them and their precursors in the region to survive a number of glacial/interglacial cycles, why might they have come to grief for thermal reasons late in MIS3? Looking at a generalized temperature curve for the last few glacial cycles (Fig. 2a), MIS3 does not appear much different – milder on average, and at its worst no colder, than MIS4 (a 'mini LGM' *c*. 75,000–70,000 BP), MIS6 (the penultimate glaciation) or MIS2 (the LGM). Yet, on closer scrutiny, there *is* something unusual: a series of 'abrupt, whiplash' fluctuations of great magnitude (Macdougall 2006: 205). These sudden, severe environmental upheavals would be challenging for many reasons, as the Stage 3 Project emphasized. However, their true significance lies in their special implication for *cold* stress.

Oxygen isotope graphs relate to temperature, but the other main component of cold stress is wind velocity. Alas, there exist no good palaeoenvironmental proxies for wind comparable to isotope proxies for temperature. The best available wind proxy is dust – stronger winds result in more atmospheric dust (loess being the classic example), but

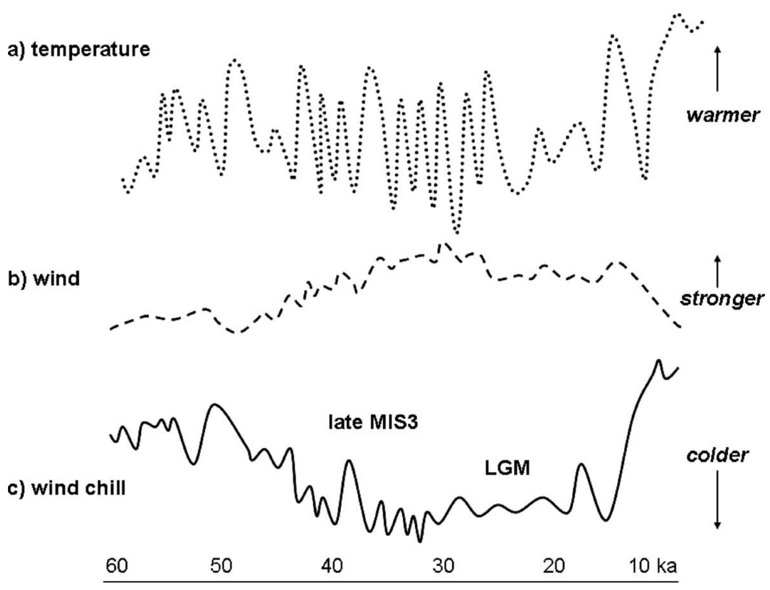

Figure 2 Schematic graph showing a) generalized temperature curve, b) possible wind velocity averages and c) hypothetical wind chill levels spanning the last 60,000 years.

aridity can also contribute to the dust record. One long-term dust analysis (covering 740,000 to 0 BP) is from Dome C in East Antarctica (EPICA 2004). This shows a marked difference for the last Ice Age: more dust than preceding glaciations, with a peak in late MIS3–MIS2, and it is unlikely that all this extra dust is attributable to greater aridity. Moreover, there is reason to expect stronger winds late in MIS3.

A fundamental factor affecting average global wind velocity is the temperature difference between the equatorial and polar zones. During ice ages, the poles cool more than the tropics, so the temperature difference is greater and ice ages are generally windier, especially in the middle latitudes, being the meat in the sandwich, so to speak. However, one other factor is relevant in MIS3: the *rapidity* of the temperature changes. More rapid changes cause stronger winds, especially when the changes are of high magnitude, which is precisely what pertained during these cold spikes.

The likely scenario is that these cold spikes corresponded to wind spikes (Fig. 2b), and the implications for the corresponding wind chill spikes are dramatic (Fig. 2c). In terms of wind chill, it is quite possible that thermal conditions in these spikes were at times more dangerous for humans than at any other time in the last Ice Age, including the LGM. The coldest wind chill conditions in MIS3 may have been brief but, in terms of the risks to human survival, a period as short as a few weeks or even less could be catastrophic for groups without sufficient portable protection.

Hypothermia as the cause of Neanderthal extinction

To what extent is cold stress – hypothermia – implicated as a *direct* cause of Neanderthal extinction? Is there any direct evidence? The short answer is no. Strangely enough, that is what should be expected. Like an ice dagger that soon dissolves, it leaves no trace of a weapon, at least not of the osteological variety. The victim can appear perfectly healthy (aside, that is, from being dead). What about other kinds of cold injury, especially frostbite? This can leave osteological evidence – X-rays of the Tyrolean Iceman, for instance, revealed signs of frostbite in one of his toes (Murphy et al. 2003: 623) – but resistance to frostbite is a prominent feature of biological cold adaptation. We should not expect to find much evidence for frostbite among Neanderthals; their likely lack of substantial footwear merely underlines the point.

Is there any indirect evidence? The short answer is yes. The whole settlement record for Neanderthals demonstrates their sensitivity to modest levels of cold. The picture for late MIS3 is most telling in this regard, as the Stage 3 Project made clear: 'If Neanderthals only had a limited cultural capability of insulating themselves, even to the modest level of 1 clo, they would have had difficulty under the increasingly harsh conditions of the latter half of OIS-3' (Aiello and Wheeler 2003: 156). In effect, if Neanderthals did not have complex clothing, they were finished. Is there archaeological evidence that they had only 'a limited cultural capability of insulating themselves' (i.e. only simple clothes)? Yes, there is, and it's called the Mousterian. Without having had much physiological need to push clothing technologies to the next level, they were insufficiently prepared for the late MIS3 wind chill spikes. Given the suddenness and severity of the spikes, *pre*-adaptation rather than adaptation was required.

Stage 3 Project findings

If the findings of the Stage 3 Project are, as argued here, consistent with hypothermia (and inadequate clothing) as the cause of Neanderthal extinction, why did the research team stop short of blaming the cold directly? They did consider it – in more detail than previous analyses – and include it as a possible contributory factor. There are a number of reasons why they hedged their bets. One is their use of multi-millennia averaged time-slices to estimate average thermal conditions rather than looking at the shorter spikes. For the coldest spikes, they used the LGM figure, which is probably reasonable for minimum temperatures but not necessarily for wind velocities – hence a likely underestimate for the severity of the late MIS3 wind chill spikes. Another drawback is their use of a wind chill formula (Aiello and Wheeler 2003: 151) that may exaggerate sub-zero wind chill estimates for given wind velocities, leading to unreliable figures for calculated tolerance levels. The main shortcomings, however, are a failure to distinguish simple from complex clothing and to recognize the technological connections with Mousterian and Upper Palaeolithic industries respectively.

Other thermal factors

While cold stress (hypothermia due to insufficient clothing) is alone sufficient to account for Neanderthal extinction, inadequate portable insulation has additional ramifications for Neanderthal survival prospects. Mobility in the open would be compromised, affecting their hunting and gathering activities, and hence their capacity not only to meet higher caloric needs but also to obtain the raw materials for clothing. Fertility rates would have been affected, not only by adult mortality but especially by higher infant mortality, as the markedly greater surface area to volume ratio of infants (combined with an immature thermoregulatory system) renders infants more prone to hypothermia.

The Chatelperronian – too little, too late

The obvious question is: why did Neanderthals not begin to develop complex clothing? The short answer is: they did. It is called the Chatelperronian. A longer answer is: they did not need to, at least not until late (as it happened, too late) in MIS3.

Looking first at the longer answer, the very biological adaptations that allowed them to manage for so long with simple clothing also meant they did not need to undertake the more labour-intensive manufacture of complex clothes. Up to a point, they would not have felt the cold as acutely as did fully modern humans. Whether any greater body hair cover made more tightly fitted garments uncomfortable is debatable, although it probably would make multi-layered clothing almost superfluous (again, until it was rather too late). Another aspect is their shortened limbs, the reduced surface area of which reduced the need for the specially cut sleeves and leg coverings of fitted garments.

The short answer, the Chatelperronian, is the subject of debate in terms of Neanderthal 'cultural' capacities and whether the new skills were acquired from fully modern humans or were an independent innovation of Neanderthals (Zilhão et al. 2006). The thermal model proposed here need not buy into the debate. It simply points out that there is no reason not to expect that Neanderthals would begin to develop at least some elements of complex clothing (e.g. tailoring, evidenced by bone awls) once their options were narrowed and especially as their situation became desperate. In any case, the Chatelperronian demonstrates that they had a capacity for such behaviour, and the need for complex clothing provides a pragmatic reason for why such technologies should suddenly become useful (or adaptive) for Neanderthals late in MIS3.

Modern humans and clothing

Just as the Neanderthals' biological cold adaptations served as disincentives for developing complex clothing, the reverse was true for fully modern humans. Biological adaptations to heat were crucial to their survival in Africa – summers remained hot even during ice ages, so biological heat adaptations were retained, ruling out opposing cold adaptations. A heightened vulnerability to cold meant that fully modern humans were prompted to begin developing complex clothing before MIS3. Following the last interglacial, which was warmer than the present one, intensifying selection for heat adaptations, a series of cold spells between 118,000 and 70,000 BP (MIS5d, MIS5b and particularly MIS4) provided the incentive for behavioural cold adaptations. The relatively longer limbs of fully modern humans (suited to maximizing heat loss) would favour an early adoption of fitted garments. Thermal considerations predict that Mode 4 technologies should make their appearance earlier in the more northern and southern parts of Africa, and more so during these colder episodes. The occurrence of perforated beads in Africa and the Levant dating to *c*. 72,000 BP (MIS4) and perhaps from the very beginning of the last Ice Age (MIS5d-5b) is pertinent, being cited as key evidence for behavioural modernity (and 'symbolic thinking') in the African MSA (Middle Stone Age), prior to the European Upper Palaeolithic (Henshilwood et al. 2004; Jacobs et al. 2006; Vanhaeren et al. 2006). The recent use of genetic studies on human body lice (which lives on clothing) for dating the origin of clothing – at least, the earliest date for its regular use among fully modern humans – to early in the last glacial cycle (Kittler et al. 2003, 2004) is also consistent with this scenario, although there are methodological problems with this approach (Reed et al. 2004) and the biomolecular date based on lice is best considered uncertain (Reed pers. comm.).

Modern human behaviour and complex clothing

The same thermal principles that connect Neanderthals with their Mousterian (and Chatelperronian) technologies lead logically to the emergence of LSA/Upper Palaeolithic technologies and modern human behaviour among fully modern humans (see McBrearty and Brooks (2000: 491–2) for a list and discussion of the archaeological 'signatures' of modern human behaviour).

Components of modern human behaviour that can be linked to thermal adaptations include technologies (particularly utilization of blade-based lithics and bone implements in the manufacture of complex garment assemblages) and also some less tangible aspects (Table 2). Among the latter are greater control of fire (e.g. more structured hearths), specialized hunting, more sophisticated artificial shelters, greater residential sedentism (and greater structuring of domestic space), increased use of pigment (connected with hide preparation as well as decoration) and archaeological signs of personal adornment and symbolism (Gilligan in press b).

Rather than attributing the emergence of modern behaviour to purported cognitive changes that are strangely decoupled from the emergence of anatomical modernity, the regionally variable and often delayed appearance of its various components may be understood as adaptations to changing environmental conditions (d'Errico 2003: 199). Discoveries in parts of Africa – especially southern Africa, and during MIS4 (e.g. Henshilwood et al. 2001; Soriano et al. 2007) – point to an African origin of developments traditionally regarded as primarily European phenomena, including signs of modern human behaviour. Moreover, both the African origins and the later Eurasian intensification of the trends during the LGM are accommodated in this thermal model, as is the absence or very late appearance of many archaeological signatures in other (warmer) parts of the world, notably in the tropics and the Australian region.

The Upper Palaeolithic

The significance of the Upper Palaeolithic is that it illustrates how the intensification of modern human behaviour in Ice Age Europe coincides with increased exposure to more intense cold. In particular, the predominance and elaboration of Mode 4 technologies in Upper Palaeolithic toolkits (e.g. bone awls and techniques for mass-producing blades) corresponds to a greater use and refinement of complex clothing. Humans equipped with these technologies were able to exploit wider territorial ranges despite colder conditions

Table 2 Archaeological signatures of behavioural modernity that can be associated with complex clothing and related thermally adaptive developments

Archaeological signature of behavioural modernity
Range extension to previously unoccupied environments (cold)
New lithic technologies (blades)
Tools in novel materials (bone)
Greater control of fire (e.g. stone-lined hearths)
Site reoccupation and modification (greater use of sheltered sites)
Specialized hunting (for meat and hides/furs)
Personal adornment (beads and ornaments)
Increased use of pigment
Grindstones (ochre-grinding)
Parietal art (and other external images and representations)
Increased artefact diversity and standardization (functional variation)
Geographic/temporal variation in formal tool categories
Mining (for pigments)

and enter northern zones that had been off-limits to those (whether Neanderthals *or* fully modern humans) without such technologies (e.g. Pavlov et al. 2004).

One pragmatic repercussion of complex clothing is that the routine and more complete covering of the skin surface with clothing means that decorative and symbolic modification of the human body is displaced elsewhere, onto garments and even externally onto the physical surroundings. Adornment of the unclad body typically leaves little trace in the archaeological record, but once these decorative and symbolic functions are transferred onto clothing and onto other media external to the body, they become more visible in the archaeological record. Rather than reflecting any heightened mental capacity for such behaviour, an increased frequency of parietal art reflects a shift from artificial modification of the exposed skin surface onto alternative surfaces such as cave walls and also into other material forms (such as figurines), once access to the skin is restricted by its routine and almost complete concealment with complex clothes. This is why, rather than any lack of cognitive, linguistic or other capacities, archaeological signs of such capacities are largely absent among Neanderthals.

Modern human behaviour in Aboriginal Australia

That absence of archaeological evidence for modern behavioural capacity cannot be taken as evidence for the absence of such capacity is made clear by the example of Australia (Brumm and Moore 2005: 169; O'Connell and Allen in press). Furthermore, there is little that corresponds to the LSA/Upper Palaeolithic in late Pleistocene Australia and, in comparison to mid-latitude Eurasia, only modest development of MSA/Middle Palaeolithic technologies. One plausible reason is simply that the use of clothing in Aboriginal Australia – even simple clothing – was largely absent from the outset. Humans who moved out of Africa and eventually into Australia by 45,000 BP probably did so without needing to venture far outside the tropics (Oppenheimer 2004; Bulbeck in press), and would have had little if any thermal need for clothes.

A thermal view of modern human behaviour nonetheless predicts that its archaeological signs should begin to appear in Australia if and when wind chill levels approached physiological limits. Indeed, given the general paucity of the archaeological markers in Australia, this region is an excellent test case. The expectation is that any evidence in Australia should be found in the cooler southern regions, especially during the coldest period, the LGM – and that is exactly what has been found.

Clothing signatures in Ice Age Tasmania

The late Pleistocene developments in Tasmania bear striking parallels to those seen in the northern mid-latitudes and stand in stark contrast to the rest of Australia. The archaeological record documents greater use of caves and rock shelters for protection from wind chill (especially in winter), a focus on manufacturing typologically distinct stone scraper tools for preparing hides, the use of bone points (though not perforated needles) for piercing the hides and targeted hunting of the major local fur-bearing species, the red-necked wallaby (Gilligan 2007; Gilligan in press b). Cave art too makes a brief appearance (e.g. Cosgrove and Jones 1989). However, thermal conditions required only simple clothing and technological requirements correspond to Mode 3. With respect to bone points or awls, the need arose because small wallaby hides had to be joined together to make adequate cloaks. Other typical signatures of complex clothing (such as blade tools and eyed needles) remained conspicuously absent. The other striking aspect is that these signatures begin to disappear from the archaeological record with the onset of warmer climates in the early Holocene, since the Tasmanians were free largely to dispense with simple clothing after the Ice Age.

Two problems, one solution

The aim here has been to demonstrate, in principle, how the Palaeolithic development of clothing can be rendered more visible archaeologically – and why this matters. It can help resolve both the paradoxical demise of cold-adapted Neanderthals during severe cold spikes preceding the LGM, along with the otherwise problematical delays in the early appearance (and the uneven presence) of behavioural modernity in fully modern humans. Unlike existing approaches, clothing-related issues (both physiological and technological) directly address fundamental aspects of the big picture and make no unfounded assumptions about nebulous cognitive, linguistic or other capacities, the evidence for (and relevance of) which is hardly more substantive than are physical remains of Pleistocene clothing. Likewise, it negates any need to attribute the enigmatic Chatelperronian to contact between Neanderthals and fully modern humans, and similarly any need to invoke competition between these two human groups. It does, however, uncover pragmatic reasons for the emergence of behavioural modernity and equally pragmatic reasons why it conferred advantages upon many (though not all) groups of fully modern humans in the context of late Pleistocene climatic changes.

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School of Archaeology & Anthropology, The Australian National University

References

Adler, D. S., Bar-Oz, G., Belfer-Cohen, A. and Bar-Yosef, O. 2006. Ahead of the game: Middle and Upper Palaeolithic hunting behaviors in the southern Caucasus. *Current Anthropology*, 47: 89–118.

Aiello, L. C. and Wheeler, P. 2003. Neanderthal thermoregulation and the glacial climate. In *Neanderthals and Modern Humans in the European Landscape during the Last Glaciation: Archaeological Results of the Stage 3 Project* (eds T. Van Andel and W. Davies). Cambridge: McDonald Institute, pp. 147–66.

Bader, O. N. and Bader, N. O. 2000. Upper Palaeolithic site Sunghir. In *Homo Sungirensis: Upper Palaeolithic Man: Ecological and Evolutionary Aspects of the Investigation* (eds T. I. Alexeeva and N. O. Bader). Moscow: Scientific World, pp. 21–9.

Bar-Yosef, O. 2002. The Upper Paleolithic revolution. *Annual Review of Anthropology*, 31: 363–93.

Brumm, A. and Moore, M. W. 2005. Symbolic revolutions and the Australian archaeological record. *Cambridge Archaeological Journal*, 15: 157–75.

Bulbeck, D. In press. Where river meets sea: a parsimonious model for *Homo sapiens'* colonization of the Indian Ocean rim and Sahul. *Current Anthropology*.

Burton, A. C. and Edholm, O. G. 1955. *Man in a Cold Environment: Physiological and Pathological Effects of Exposure to Low Temperatures*. London: Edward Arnold.

Clark, J. G. D. 1977. *World Prehistory in New Perspective*, 3rd edn. Cambridge: Cambridge University Press.

Cosgrove, R. and Jones, R. 1989. Judd's Cavern: a subterranean Aboriginal painting site, southern Tasmania. *Rock Art Research*, 6: 96–104.

d'Errico, F. 2003. The invisible frontier: a multiple species model for the origin of behavioral modernity. *Evolutionary Anthropology*, 12: 188–202.

EPICA community members 2004. Eight glacial cycles from an Antarctic ice core. *Nature*, 429: 623–8.

Gagge, A. P., Burton, A. C. and Bazett, H. C. 1941. A practical system of units for the description of the heat exchange of man with his environment. *Science*, 94: 428–30.

Gilligan, I. 2007. Resisting the cold in ice age Tasmania: thermal environment and settlement strategies. *Antiquity*, 81: 555–68.

Gilligan, I. In press a. *Another Tasmanian Paradox: Clothing and Thermal Adaptations in Aboriginal Australia*. BAR International Series. Oxford: Archaeopress.

Gilligan, I. In press b. Clothing and modern human behaviour in prehistoric Tasmania. *Archaeology in Oceania*.

Gilligan, I. Submitted. Clothing in Aboriginal Australia: implications for clothing origins and prehistoric archaeology. *Current Anthropology*.

Hayden, B. 1990. The right rub: hide working in high ranking households. In *The Interpretative Possibilities of Microwear Studies* (eds B. Gräslund, H. Knutsson, K. Knutsson and J. Taffinder). Uppsala: Societas Archaeologica Upsaliensis, pp. 89–102.

Hensel, H. 1981. *Thermoreception and Temperature Regulation*. Monographs of the Physiological Society No. 38. London: Academic Press.

Henshilwood, C. S., d'Errico, F., Marean, C. W., Milo, R. G. and Yates, R. 2001. An early bone tool industry from the Middle Stone Age at Blombos Cave, South Africa: implications for the origins of modern human behaviour, symbolism and language. *Journal of Human Evolution*, 41: 631–78.

Henshilwood, C. S., d'Errico, F., Vanhaeren, M., van Niekerk, K. and Jacobs, Z. 2004. Middle Stone Age shell beads from South Africa. *Science*, 304: 404.

Hublin, J.-J. 1998. Climatic changes, paleogeography, and the evolution of the Neandertals. In *Neandertals and Modern Humans in Western Asia* (eds T. Akazawa, K. Aoki and O. Bar-Yosef). New York: Plenum Press, pp. 295–310.

Hublin, J.-J., Ruiz, C. B., Lara, P. M., Fontugne, M. and Reyss, J.-L. 1995. The Mousterian site of Zafarraya (Andalucia, Spain): dating and implications on the Palaeolithic peopling processes of Western Europe. *Comptes rendus de l'Académie des Sciences série IIa*, 321: 931–7.

Jacobs, Z., Duller, G. A. T., Wintle, A. G. and Henshilwood, C. S. 2006. Extending the chronology of deposits at Blombos Cave, South Africa, back to 140 ka using optical dating of single and multiple grains of quartz. *Journal of Human Evolution*, 51: 255–73.

Jessen, C. 2001. *Temperature Regulation in Humans and Other Mammals*. Berlin: Springer-Verlag.

Kittler, R., Kayser, M. and Stoneking, M. 2003. Molecular evolution of *Pediculus humanus* and the origin of clothing. *Current Biology*, 13: 1414–17.

Kittler, R., Kayser, M. and Stoneking, M. 2004. Erratum: molecular evolution of *Pediculus humanus* and the origin of clothing. *Current Biology*, 14: 2309.

Kuhn, S. L. and Stiner, M. C. 2006. What's a mother to do? The division of labor among Neandertals and modern humans in Eurasia. *Current Anthropology*, 47: 953–80.

Macdougall, D. 2006. *Frozen Earth: The Once and Future Story of Ice Ages*. Berkeley, CA: University of California Press.

McBrearty, S. and Brooks, A. S. 2000. The revolution that wasn't: a new interpretation of the origin of modern human behavior. *Journal of Human Evolution*, 39: 453–563.

Murphy, W. A., zur Nedden, D., Gostner, P., Knapp, R., Recheis, W. and Seidler, H. 2003. The Iceman: discovery and imaging. *Radiology*, 226: 614–29.

O'Connell, J. F. and Allen, J. In press. Pre-LGM Sahul (Australia-New Guinea) and the archaeology of early modern humans. *Cambridge Archaeological Journal*.

Oppenheimer, S. 2004. *Out of Eden: The Peopling of the World*. London: Constable & Robinson.

Parsons, K. C. 2003. *Human Thermal Environments: The Effects of Hot, Moderate, and Cold Environments on Human Health, Comfort and Performance*, 2nd edn. London: Taylor & Francis.

Pavlov, P., Roebroeks, W. and Svendsen, J. I. 2004. The Pleistocene colonization of northeastern Europe: a report on recent research. *Journal of Human Evolution*, 47: 3–17.

Quayle, R. G. and Steadman, R. G. 1998. The Steadman Wind Chill: an improvement over present scales. *Weather and Forecasting*, 13: 1187–93.

Reed, D. L., Smith, V. S., Hammond, S. L., Rogers, A. R. and Clayton, D. H. 2004. Genetic analysis of lice supports direct contact between modern and archaic humans. *PLoS Biology*, 2: e340.

Siple, P. A. 1945. General principles governing selection of clothing for cold climates. *Proceedings of the American Philosophical Society*, 89: 200–34.

Sloan, A. W. 1979. *Man in Extreme Environments*. Springfield, IL: Charles C. Thomas.

Soffer, O., Adovasio, J. M., Hyland, D. C., Klíma, B. and Svoboda, J. 1998. Perishable technologies and the genesis of the Eastern Gravettian. *Anthropologie*, 36: 43–68.

Soriano, S., Villa, P. and Wadley, L. 2007. Blade technology and tool forms in the Middle Stone Age of South Africa: the Howiesons Poort and post-Howiesons Poort at Rose Cottage Cave. *Journal of Archaeological Science*, 34: 681–703.

Speth, J. D. 2004. News flash: negative evidence convicts Neanderthals of gross mental incompetence. *World Archaeology*, 36: 519–26.

Steegmann, A. T. Jr., Cerny, F. J. and Holliday, T. W. 2002. Neandertal cold adaptation: physiological and energetic factors. *American Journal of Human Biology*, 14: 566–83.

Straus, L. G. 2005. On the demise of Neandertals. *Quaternary International*, 137: 1–5.

Trinkaus, E. 2005. Anatomical evidence for the antiquity of human footwear use. *Journal of Archaeological Science*, 32: 1515–26.

van Andel, T. H. and Davies, W. (eds) 2003. *Neanderthals and Modern Humans in the European Landscape during the Last Glaciation: Archaeological Results of the Stage 3 Project*. Cambridge: McDonald Institute for Archaeological Research.

Vanhaeren, M., d'Errico, F., Stringer, C., James, S. L., Todd, J. A. and Mienis, H. K. 2006. Middle Paleolithic shell beads in Israel and Algeria. *Science*, 312: 1785–88.

White, M. J. 2006. Things to do in Doggerland when you're dead: surviving OIS3 at the northwestern-most fringe of Middle Palaeolithic Europe. *World Archaeology*, 38: 547–75.

Wolpoff, M. H., Mannheim, B., Mann, A., Hawks, J., Caspari, R., Rosenberg, K. R., Frayer, D. W., Gill, G. W. and Clark, G. 2004. Why *not* the Neandertals? *World Archaeology*, 36: 527–46.

Zilhão, J., d'Errico, F., Bordes, J.-G., Lenoble, A., Texier, J.-P. and Rigaud, J. P. 2006. Analysis of Aurignacian interstratification at the Châtelperronian-type site and implications for the behavioral modernity of Neandertals. *Proceedings of the National Academy of Sciences USA*, 103: 12643–8.

Ian Gilligan has trained in medicine, psychology and prehistoric archaeology and holds a postgraduate scholarship at the Australian National University. His main interest is the prehistory and repercussions of clothing. His doctoral research examines human cold adaptations in the late Pleistocene and the development of clothing technologies.