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Reconsidering the link between past material culture and cognition in light of contemporary hunter-gatherer material use.

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Abstract

Many have interpreted symbolic material culture in the deep past as evidencing the origins sophisticated, modern cognition. Scholars from across the behavioural and cognitive sciences, including linguists, psychologists, philosophers, neuroscientists, primatologists, archaeologists and paleoanthropologists have used such artefacts to assess the capacities of extinct human species, and to set benchmarks, milestones or otherwise chart the course of human cognitive evolution. To better calibrate our expectations, the present paper instead explores the material culture of three contemporary African forager groups. Results show that, while these groups are unequivocally behaviourally modern, they would leave scant long-lasting evidence of symbolic behaviour. Artefact-sets are typically small, perhaps as consequence of residential mobility. When excluding traded materials, few artefacts have components with moderate-strong taphonomic signatures. Present analyses show that artefact function influences preservation probability, such that utilitarian tools for the processing of materials and the preparation of food are disproportionately likely to contain archaeologically traceable components. There are substantial differences in material-use between populations, which create important population-level variation preservation probability independent of cognitive differences. I discuss the factors — cultural, ecological and practical — that influence material choice. In so doing, I highlight the difficulties of using past material culture as an evolutionary or cognitive yardstick.

Short Abstract

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1.Introduction

'There may have been an array of tattoos, ice carvings, and sand paintings... but it appears intuitively unlikely that such artistic and symbolic activities might have been expressed in such inorganic and non-enduring material without having been expressed in bone and stone.'

– S. Mithen, 2013, p.223

In many regards, including our capacity for advanced cognition, sophisticated language, ritual and symbolic thought, humans are outliers among all other species. The origins of these capacities generate substantial research interest. However, as speech and behaviour are ephemeral (Berwick et al. 2013) and leave little skeletal evidence (but see Albessard-Ball and Balzeau 2018; Mounier, Noûs, and Balzeau 2020), researchers have instead sought indirect evidence (Tattersall 2017a) for the emergence of modern human cognition. For example, many interpret the proliferation (Kelly et al. 2023) of sophisticated material culture ~70,000 (Bolhuis et al. 2014; Tattersall 2017a) to 50,000 (Klein 2017) years ago as a watershed moment in human evolution, indicating 'cultural' (Conard 2010) or 'behavioural' (see Mellars 2005; Ames et al. 2013) modernity, the appearance of 'fully-fledged' (Klein 2017) recursive (Vyshedskiy 2019) language, long-rage temporal planning (Davidson 2010) and travel (Davidson and Noble 1992), a capacity for systematising (Baron-Cohen 2020), abstract, symbolic (Klein 2017), complex (Bolhuis et al. 2014) thought, perspective-taking (Henshilwood and Dubreuil 2009), enhanced working memory, executive function (Wynn et al. 2009; Wynn and Coolidge 2010; Coolidge et al. 2012), increased cognitive fluidity (Mithen 2013), ritual (Watts et al. 2016), a cognitive capacity for culture (Kelly et al. 2023), and other types of 'complex' (Wadley 2021) or 'enhanced' (Klein 2017) cognition. Material evidence has also played a major role in exploring the cognitive capacities of other human species, and comparing them to our own (e.g., Finlayson et al. 2012; Kozowyk et al. 2017; Hoffmann et al. 2018; Turk et al. 2018; Schmidt et al. 2019; Hardy et al. 2020; Baquedano et al. 2023). For instance, the association of symbolic (Zilhão et al. 2010; Baquedano et al. 2023) and complex material culture (Kozowyk et al. 2017; Hardy et al. 2020) including artwork (Hoffmann et al. 2018) with Neanderthals has led, in recent years, to a revised consensus on Neanderthal cognition (Zilhão et al. 2010; Sykes 2015) and greater recognition of their 'shared humanity' (Breyl 2021).

Behaviour/Capacity	Proposed Artefactual Evidence	Reference
Language	Artistic Expression; Cave Painting	Tattersall (2017b)
	Unquestionable Symbolic Art; Personal Ornaments	Klein (2017)
	Symbolic Objects; Engraving; Pierced Shell Beads; Art	Bolhuis et al. (2014)
	Composite figurative arts; Eyed needles; Dwelling Construction; Elaborate Burial	Vyshedskiy (2019)
	Backed Lithics; Elaborate/Decorative Tools; Personal Ornaments; Engraving	Henshilwood and Dubreuil (2009)
Symbolic Behaviour	Personal Ornaments; Symbolic ornamental items; Artistic or Decorative Items	Mellars (2005, 2020)
Ritual Behaviour	Pigment Use and Transport	Watts et al. (2016)
	Crystal Transport	Wilkins et al. (2021)
Complex Communication Systems	Personal Ornaments; Beadwork	Vanhaeren et al. (2013)
Working Memory	Snares/Traps; Hafting; Weaponry; Figurines; Beads	Coolidge et al. (2012)
	Complex Composite Tools	Haidle (2010)
Advanced Planning	Oceanic Travel; Boat Making	Davidson and Noble (1992)
	Oceanic Travel	Leppard (2015)
	Composite Tools; Material Transport; Broadened Material Selection	Ambrose (2010)
Cognitive Fluidity & Creative Thought	Beads; Figurines; Artwork	Mithen (2013)
Systematising Thought	Engraving, Jewellery, Bows and Arrows; Boats; Needles; Musical Instruments	Baron-Cohen (2020)
Complex Cognition	Lithic Heat Treatment; Compound Tools; Glues; Compound Paints; Snares	Wadley et al. (2009); Wadley (2013)
	Grass Bedding; Bedding Ash	Wadley et al. (2020)
Behavioural Modernity	Compound Tools; Burials; Colorants; Adornment; Engravings; Figurines; Instruments	Nowell (2013)

Table 1: A non-comprehensive table of proposed criterion evidencing different aspects of modern behaviour and cognition. The current investigation focusses on symbolic evidence, broadly construed, although the same dataset could be coded to address other evidence types.

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However, while some have considered contemporary hunter-gatherers in discussions of cognitive evolution (Shea 2011b; Haidle 2016; Killin and Pain 2023; Sterelny 2021a), no quantitative studies have systematically investigated whether cognitively modern human populations would *themselves* necessarily leave enduring material evidence of these capacities. This is important, as contemporary differences in material culture do not indicate cognitive capacity differences, but result from more practical concerns such as subsistence ecology, material availability, resource stochasticity, residential movement, alongside technological ratchets and demographically mediated innovation, transmission and knowledge loss (Collard et al. 2011; Shott 1986; Henrich 2004; Sterelny and Hiscock 2024; Sterelny 2021b). This study examines three near-complete records of material culture from three African forager groups, with particular focus on symbolic artefacts. Results show that many fully modern human populations would leave scant material evidence of their modernity, however defined. I critically examine the utility of similar types of evidence in charting the course of human cognitive evolution, and the related tendency to assume a lack of cognitive sophistication where material evidence is lacking.

2. Symbolism and Complex Technology in the Deep Past

First, it is useful to briefly review the archaeological record. Evidence for technological complexity in the human lineage has a deep history. Hafted and other multi-component tools, often seen as a stage-post in human evolution (Wadley et al. 2009; Barham 2013; Sykes 2015), have multiple centres of origin (Blinkhorn 2019) dating to perhaps 500 ka and at least 280 ka in Africa (Wilkins et al. 2012; Sahle et al. 2013) and at least 300 ka and South Asia (Blinkhorn 2019). Unhafted projectile weapons have an even deeper history, dating to perhaps 2 million years based on *Homo erectus* shoulder morphology (Roach and Richmond 2015) and at least 500 ka (Roberts 1998; Thieme 1997). The production of pitch tar adhesive, perhaps by distillation, has been identified in Neanderthal contexts (Sykes 2015, but see Schmidt et al. 2019) dating to 200 ka. The use of charcoal in bedding, potentially as insect repellent (Wadley et al. 2020), dates to 200 ka. The heat-treatment of raw materials in tool manufacture dates to perhaps 164 ka (Murray et al. 2020). Moreover, the creation of wooden structures with joinery dates to 476,000 ka (Barham et al. 2023).

Plausible evidence of ‘symbolic behaviour’ also has a deep history. Evidence for ochre pigment processing, seen by some as indicative of ritual (e.g., Barham 2016) or symbolic thought (but see Mithen 2014) occurs in Neanderthal contexts, dating to at least 200-250 ka (Roebroeks et al. 2012). Evidence for ochre use among *Homo sapiens* or direct ancestors dates to as early as 295 ka in Kenya (Brooks et al. 2018) and 260 ka in Zambia (Barham 2002). Evidence of pigment use and transport dates back even earlier, e.g., perhaps 500-300 ka in South Africa (Watts et al. 2016) although its ritual function is contentious (Barham 2016). Perforated shell beads appeared in north Africa at least 142 ka (Sehasseh et al. 2021), the Levant by 120 ka (Mayer et al. 2020), and by 70-80 ka in southern Africa (d’Errico and Backwell 2016; Vanhaeren et al. 2019). Non-perforated shells from Israel also with a proposed symbolic function date to between 240-160 ka (Mayer et al. 2020). Moreover, one temporally isolated carved mussel shell was found in *Homo* *erectus* contexts from ~540-440 ka in Java, Indonesia (Dubois 1908; Joordens et al. 2015). The collection and transport of manuports — unmodified materials, with no clear utility — has also been highlighted as potentially indicating ritual behaviour (Wilkins et al. 2021). Stone manuports are ancient, appearing in Oldowan contexts (Dart 1974; Granger et al. 2015) >2 MA. The collection of crystalline manuports dates to 105 ka (Wilkins et al. 2021) in South Africa, while the collection of non-food seashells dates to at least 90 ka in South Africa (Marean 2010) and the Levant (Bar-Yosef et al. 2009).

Although complex and symbolic artefacts exist from great time-depths (McBrearty and Brooks 2000; Barham et al. 2023; Joordens et al. 2015), many scholars contend that 70-50 ka was yet characterised by rapid transformation, innovation and change in the artifactual record (Kelly et al. 2023). From 50 ka and beyond, there are numerous examples of 'indisputable art and personal ornaments' (Klein 2017, 204), including carved ivory figures such as the German Hohle Fels Venus (35 ka; Conard 2009) and Hohlenstein-Stadel lion-man (32-30 ka; Hahn 1986; Wynn et al. 2009). The earliest examples of representational art come from Sulawesi, Indonesia, including depictions of hunting scenes in Sipong Cave, (43.9 ka; Aubert et al. 2019) and depictions of wild pigs from Leang Tedongnge cave (45.5 ka; Brumm et al. 2021). Examples of possible figurative art exist from potentially greater time-depths, including dot art and hand stencils from Northern Spain (Hoffmann et al. 2018). These date to perhaps earlier than 64.8 ka, which would associate them with Neanderthals (Hoffmann et al. 2018), although their age and provenance remain disputed (see White et al. 2020). Many argue that the appearance of polished ostrich eggshell beads in Africa (see d'Errico et al. 2020) and China (Wei et al. 2017) during the same timeframe, represents a similarly profound transformation (e.g., Klein 2017).

In addition to establishing and updating material chronologies, many have looked to this record to address broader questions about past minds, brains and the cognitive evolution of our lineage.

3.Linking Material Culture to Cognition, Language and Behaviour

The profusion of symbolic behaviour, especially beyond 70 ka (see Kelly et al. 2023), has led many to favour a 'recent' origin of modern human behaviour (Klein 2019; Mellars 2010). The criteria for defining and identifying 'modernity' vary (see Table 1) but the underlying logic of these hypotheses is often similar. Berwick et al. (2013, p.1) set this out clearly in the context of language evolution: 'Symbolic behavior, as in cave painting, is an indirect proxy for language, and its earliest indications come from... sites dated at roughly 100 kyr or less... Archaeology thus supports a recent timeframe for the emergence of modern behaviors associated with language: substantially after the emergence of *Homo sapiens*'. Chronologies differ between sources. Some prefer an earlier date (discussed McBrearty 2013). Others prefer an even later date, and, for instance, Klein (2017) argues that 'irrefutable art and personal ornaments, appeared only 50-40 ka, which suggests this was also when full-fledged language appeared' (p.217). The specific faculties under consideration also vary (see Table 1). Some concentrate on language origins (Tattersall 2017a), abstract representation or 'complex symbolic thinking' (Mellars 2010; Klein 2017) and recursive or hierarchical syntax (Bolhuis et al. 2014; Vyshedskiy 2019). Others consider capacities such as systematising thought (Baron-Cohen 2020), working memory (Wynn et al. 2009; Wynn and Coolidge 2010), imagination, creativity and neural connectivity (Wadley 2021) or cognitive fluidity (Mithen 2013).

There are different views on whether cognitive change occurs via genetic/somatic/or neural differences or via culturally transmissible extra-somatic inventions. Some contend that any 'revolution' in human cognitive ability was accompanied by change in the substrates of the brain (Klein 2008, 2017, 2019; Wynn et al. 2009 and, with caveats, Mellars 2005). Others suggest that the 'capacity for culture' (Kelly et al. 2023) or the 'language-ready brain' (Tattersall 2017a; Bolhuis et al. 2014) evolved alongside archaic *Homo sapiens*, and enabled but pre-dated language or certain forms of cultural expression. Many such theories still predict somatic, neural or other intrinsic capacity differences between *Homo sapiens* and Neanderthals (Tattersall 2017a), or between earlier and later *Homo sapiens* (Kelly et al. 2023). Some see cultural and somatic evolution as being intertwined and propose a gene-culture feedback loop between capacity and expression (Wadley 2021). Some separate 'behavioural modernity' from somatic change or intrinsic capacities entirely: Sterelny (2011), for instance, sees behavioural modernity not as 'coded and canalised' but as an extrinsic 'collective capacity to retain and upgrade rich systems of information and technique' (p.814), which is 'dependent on the organization of social life' (p.819).

Beyond the academy, 'recent origins' theories have been influential in shaping public perceptions of prehistory. Certain popular texts such as *Sapiens: A Brief History of Humankind* (Harari 2014), its graphic adaptation (Harari et al. 2020) and others (e.g., Baron-Cohen 2020), present the 'recent origins' model of language as a resolved consensus theory. For example, Harari et al. (2020, p.61) state that after 70,000 ka we see 'the first objects that we can reliably call jewellery' which 'most researchers say... came down to a revolution in sapiens' cognitive abilities'. Though not all popular texts promote this view (Sykes 2020; Graeber and Wengrow 2021), those that do have been highly influential and nativist (*sensu* Sterelny 2019) recent origins theories have filtered into other forms of popular media (Kurzgesagt 2016).

Within the academy, recent origins and 'revolution' theories have been vigorously debated. Some propose a deep origin of sophisticated linguistic ability (e.g., Albessard-Ball and Balzeau 2018; Mounier, Noûs, and Balzeau 2020). Many highlight earlier artifactual evidence of symbolic behaviour (McBrearty and Brooks 2000; McBrearty 2013), especially outside of Europe (McBrearty 2007). Evidence of symbolism in Neanderthal contexts (e.g., Zilhão et al. 2010; Nowell 2013; Hoffmann et al. 2020) — who diverged from *Homo sapiens* 700-400 ka (see Stringer 2016) — has fuelled phylogenetic arguments for early origins of symbolic capacity (see Zilhão 2007; Mellars 2010; Leder et al. 2021).

Some have questioned the extent to which specific artefacts actually do evidence linguistic ability or symbolic capacity (Kuhn and Stiner 2007; Botha 2010; Sterelny 2014, 2011). Ochre, for instance may have prosaic and functional uses, for example as camouflage, insect repellent, an adhesive (Wadley 2005; Sterelny 2011) or a threat display (Kuhn and Stiner 2007; Sterelny 2011). Similarly, the link between material culture and certain aspects of syntactic or linguistic ability is not concrete (Henshilwood and Dubreuil 2011; Botha 2010; Sterelny 2014). Personal adornment may engage different neural systems to those employed in creating and decoding spoken utterances (Sterelny 2014) and, for instance, children's understanding of symbols does not parallel the ontogeny of syntax (Henshilwood and Dubreuil 2011).

Others have highlighted more general difficulties in reading the material record (Speth 2004; Zilhão et al. 2010; Dibble et al. 2017; Shea 2011b; Haidle 2016; Ames et al. 2013; Scerri and Will 2023), including the risks of ignoring differences in preservation environments and material choices (Shea 2011b; Langley et al. 2011), the risk of over-attributing manufacturer intent to the structure of assemblages (Dibble et al. 2017), the risk of creating false dichotomies and thresholds (Ames et al. 2013), the inferential gap between performance and capacity (Haidle 2016), and the related risk of using absent evidence to infer absent capacity (Speth 2004; Zilhão 2007).

Both primate and hunter-gatherer archaeologists have considered the importance of perishable media (Milks 2020; Pascual-Garrido and Almeida-Warren 2021) and contended that complex perishable technologies substantially pre-date even the earliest lithic industries (Pascual-Garrido and Almeida-Warren 2021). There has been extensive debate about the extent to which behavioural modernity and language are intrinsic (e.g. Klein 2019; Mellars 2010) or culturally acquired (Sterelny 2011, 2016; Tattersall 2017b). Cultural transmission of technologies (Speth 2004) and the role of population size and structure in driving innovation are presented as alternative hypotheses to somatic change (Henrich 2004; Powell et al. 2009; Henrich et al. 2016; Sterelny 2021a; Scerri and Will 2023; but see Klein and Steele 2013; Vaesen et al. 2016). Others argue that differences in material culture should be conceptualised not as markers of changing cognition, but as responses to varying environments (Hopkinson 2011; Shea 2011b; d'Errico and Stringer 2011) — although material variability has, itself, sometimes been used to chart cognitive evolution (e.g., see discussion by Nowell and White 2010; Tennie et al. 2016; Wadley 2016; Shea 2017). Several have pointed to the difficulties of defining cognitive and linguistic 'modernity' (d'Errico 2003; Stringer 2002; Shea 2011b) or otherwise critiqued the notion of behavioural modernity as an analytically useful concept (Shea 2011b; Ames et al. 2013; Scerri and Will 2023).

Despite continued discourse concerning recent origins theories (Klein 2017; d'Errico et al. 2020; Scerri and Will 2023), over the last decade research consensus has towards gradualistic (McBrearty 2013), and mosaic (Conard 2015; Scerri et al. 2018) theories of evolutionary change. Pure cultural evolutionary accounts, which assume no difference in intrinsic capacity, either within our species (Tattersall 2017a), or broadly (Sterelny 2016, 2019) have become more widely accepted. Focus has also shifted to explorations of species-level differences (Wynn et al. 2016). Here too, however, discussions of symbolism and complexity in material culture are still at the fore. Both cord-making and birch pitch tar production have been pivotal to debates about Neanderthal cognition and planning depth (see Kozowyk et al. 2017; Schmidt et al. 2019; Hardy et al. 2020). Neanderthal personal adornment (Finlayson et al. 2012), burial (Pomeroy et al. 2020), art (Hoffmann et al. 2018; White et al. 2020), non-subsistence-related faunal assemblages (Baquedano et al. 2023) and musical instruments (Turk et al. 2018) are frequently used as evidence both for (Hardy et al. 2020; Breyl 2021) and against (Schmidt et al. 2019; Wynn et al. 2016) Neanderthals possessing, e.g., 'symbolic thought' or 'modern human' cognitive capacity. These recent debates have fruitfully challenged assumptions (Breyl 2021; Baquedano et al. 2023) that Neanderthals had less advanced (e.g., see Mithen 2014; Speth 2004) or substantively different (e.g., see Wynn et al. 2016) cognitive capacities to modern *Homo sapiens*; but they yet risk perpetuating the assumption that material evidence of complexity is *necessary* for past populations to be considered cognitively modern.

4. Absence of Evidence, Evidence of Absence, Denying the Antecedent and the Primitive Null

Given the limited evidence available, it is important to squeeze 'every last bit of data... from the archaeological record' (Overmann and Coolidge 2019, p.6). However, when considered in light of contemporary forager ethnography, it becomes clear that there are inferential difficulties in linking cognition to material culture. Contemporary foragers are *just as cognitively sophisticated* as other contemporary human populations. Yet, even despite access to metals and plastics, alongside extensive exchange with neighbouring agricultural groups in goods and ideas, many have artefact sets smaller and less elaborate than those associated with Upper Palaeolithic Europe. Many do not routinely create paintings, bury their dead with symbolic grave goods (Woodburn 1982), create ochre-based pigments, or engage in certain other activities used as proxies (Wadley 2021; Henshilwood and Dubreuil 2009; Klein 2017; Mellars 2005) for past behavioural complexity.

Thus, the use of material cultural in charting the trajectory of cognitive evolution appears to represent a 'denying the antecedent' fallacy: i.e., where 'A' implies 'B', it does not follow that 'not A' implies 'not B'. In other words, while evidence of sophisticated material culture might provide positive evidence of cognitive sophistication (Finlayson et al. 2012; Lombard and Haidle 2012; Haidle 2016; but see Botha 2010; Sterelny 2014), the inverse — that a *lack* of sophisticated material culture demonstrates a *lack* of cognitive sophistication — is unproven. It is unclear whether complex 'modern' human cognition *requires* evidence of burial, art, symbolism or complex technology. Such evidence *may* be sufficient to prove (though, e.g., see Botha 2008, 2010; Sterelny 2014), but is not a necessary condition of cognitive complexity (see Speth 2004; Shea 2011b; Hopkinson 2011; Ames et al. 2013; Haidle 2016; Scerri and Will 2023, among others). This distinction is captured by the well-known aphorism 'absence of evidence is not evidence of absence'.

Indeed, most scholars of cognitive prehistory are careful to acknowledge the limitations of the archaeological record (Shultz et al. 2012; Wadley 2013; Mellars 2010; Kelly et al. 2023). Bolhuis et al. (2014) highlight that 'inference from the symbolic record… rests on evidence that is necessarily quite indirect' (p.4), while Mellars (2010) cautions against 'pressing the evolutionary and cognitive implications of all this too far' (p.20148). Kelly highlights that 'the empirical record is difficult to read as a straightforward document' (p.6). Sterelny (2016) makes clear that inferences from technology, demographic conditions, trade networks and movement patterns can only paint a 'fragmentary and fallible' picture 'of long-vanished hominins' (p.183). Wadley (2016) cautions that 'we can only interpret levels of cultural or cognitive complexity from circumstantial evidence'. Almost all are aware of the interpretive difficulties inherent in reconstructing past minds from material traces. Yet, while alive to these difficulties, many continue to overinterpret the material record. Here, I describe three reoccurring issues: 1) the unproven assumption that modern humans will inevitably create certain categories of enduring material evidence, diagnostic of their modernity; 2) the use of absent evidence and absence-presence transitions to advance positive hypothesis about transitions in human minds or brains; 3)

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the (null) assumption that, without positive evidence to the contrary, early *Homo sapiens* or other human species are primitive by default.

First, several researchers explicitly contend that cognitively modern humans would inevitably have created sophisticated artefacts from enduring media (Klein 2017; Mithen 2013). Mithen expresses this directly, stating 'it appears intuitively unlikely that such artistic and symbolic activities might have been expressed in such inorganic and non-enduring material without having been expressed in bone and stone' (p.223). Aronoff (2020) makes a similar claim regarding language evolution, arguing 'a relatively sudden jump in the complexity of human linguistic behavior, if it occurred, should leave immediate traces in the archeological record in the shape of a sudden jump in the complexity of preserved artefacts (tools, ornaments, and artwork)' (p.6). Similarly, Kelly et al. (2023), though they make clear that there 'were many prehistoric societies whose members were fully capable of symbolic expression but who (apparently) left behind few obviously symbolic artifacts' (p.5), also provide a qualified restatement of the same argument: 'We provisionally assume that a population cognitively capable of symbolic expression through activities that leave no trace will also participate in those that do' (p.2). They speculate, on this basis, that a cognitive capacity for culture appeared between 195 ka and 130 ka.

Second, and more commonly, researchers draw directly on absent material evidence or shifts from an absence to a presence of certain artefacts to make strong inferences concerning about the chronology and trajectory of cognitive evolution. Klein (2017) argues for rapid cognitive advancements only in the Later Stone Age because 'proposed symbolic artefacts do not occur in most MSA [Middle Stone Age] sites' (p.216). Wadley (2021) highlights the paucity of signs of imaginative technological development before 100 ka ('We see few skills in the pre-100 ka ago record that could not easily be passed on through nonverbal observation', p.131). She suggests that this paucity, relative to 'the proliferation innovative material culture after 100 ka' evidences the late appearance of 'complex cognition and brains with neural connectivity like ours' (p.134). Coolidge et al. (2012) consider and then explicitly dismiss concerns over arguing from absent evidence, concluding these set 'too strict' a standard which 'places unreasonable demands on archaeological inference' (p.16). They instead interpret the shift in the Upper Palaeolithic material record around 50,000, and the associated appearance of ivory carvings, as implying a 'cognitive "leap"... consistent with an enhancement to WM [working memory] through a genetic or epigenetic event' (p.17).

Similar absence-to-presence logic is often employed in consideration of earlier lithic evidence also and, for instance, several studies (Stout and Chaminade 2012; Stout et al. 2021) have leveraged brain imaging data to quantify technical complexity in the manufacture of Acheulean and Oldowan lithics and to infer changes in capacity. Stout and Chaminade (2012) suggest that because 'Lower Palaeolithic technology is relatively lacking in semantic content... this aspect of modern human cognition evolved later' (p.83). Nor is such logic limited to genetic or intrinsic capacity models. Sterelny (2016), uses lacking 'technical achievements' and the absence of 'overt signs of an ideological life' including ochre, jewellery, 'figurines or other objects made for non-utilitarian purpose' (p.179) as one of four categories of evidence to infer that *Homo hiedelbergensis* probably did not possess 'lexically rich protolanguage' (p.179). He contends that 'if they were standard features of mid-Pleistocene hominin life, it is likely that we would see those traces' (p.179).

Most researchers do not dismiss the inferential problems of arguing from absent evidence (Coolidge et al. 2012), or employ absent evidence to advance their theses. Almost all recognise that we cannot determine whether changes in material culture are 'the result of a cognitive advance or a more mundane process' (Shultz et al. 2012, p.2137). More commonly, however, assumptions about the cognitive capacities of ancient humans are implicit. For to invoke artifactual evidence (Conard 2015; Coolidge et al. 2016; Muller et al. 2017; Wadley et al. 2020; Barham and Everett 2021; Henshilwood and Dubreuil 2011; Stout et al. 2021; Kelly et al. 2023) in establishing a chronology for cognitive evolution, or in human species (Sykes 2015; Schmidt et al. 2019; Leder et al. 2021), is to tacitly endorse the assumption that without such positive evidence to the contrary, past humans should not be considered cognitively or behaviourally sophisticated by default.

This third tacit assumption, the 'primitive', 'plesiomorphic' or 'ancestral' null, is pervasive. It is seen in depictions of the Neanderthals, who had cutting tools and cord-making technologies (Hardy et al. 2020) yet are habitually shown in museum reconstructions with untended hair or few-to-no clothes. It is seen in discussions surrounding Neanderthal extinction, which often attend to cognitive difference (Gilligan 2007; Horan et al. 2005; Villa and Roebroeks 2014; Gilpin et al. 2016). It is seen in the disproportionate attention and impact generated by finds which push 'complex' or representational expressions further into the past (Aubert et al. 2019; Brumm et al. 2021; Schmidt et al. 2019; Hoffmann et al. 2018; Barham et al. 2023) and in the popular and scholarly discourses surrounding them (Sample 2018; Mithen 2014; Wynn et al. 2016, 2021; Schmidt et al. 2019; White et al. 2020; Hoffmann et al. 2020; Metcalfe 2023). Indeed, in an interview for the Scientific American (Metcalfe 2023) concerning the recent discovery of wooden structures from 476 ka in Zambia (Barham et al. 2023), the lead author sets out the primitive null clearly, stating 'I never would have thought that pre-*Homo sapiens* would have had the capacity to plan something like this'.

A priori, this ancestral null is not unreasonable. Humans, contrasted with our closest extant relatives, are in numerous regards, highly and perhaps uniquely derived (Maynard Smith and Szathmáry 1997; Foley 2016). More, it appears probable that the human-chimpanzee last common ancestor, though plausibly importantly different to any individual living ape (Lovejoy 2009; Sayer et al. 2012; Püschel et al. 2021 but see Whiten et al. 2010), had more in common with other extant apes than *Homo sapiens* (Kinzey 1987; Stanford and Allen 1991; McGrew 2010; Püschel et al. 2021). However, even assuming a plesiomorphic (i.e., ancestral) common ancestor between 5 (Kumar et al. 2005) and 12 (Püschel et al. 2021) ma, the trajectory and pace of human cognitive evolution remains unresolved. While physical evidence is also frequently considered (Shultz et al. 2012), current cognitive and linguistic archaeology is yet considerably enmeshed with interpretation of the material record. As such assumptions have historically often proven wrong (McBrearty and Brooks 2000, 2000; Harmand et al. 2015; Barham et al. 2023; Hoffmann et al. 2018; Shea 2011b; Breyl 2021; Scerri and Will 2023), perhaps our null model should itself be reconsidered.

5.Material Culture, Symbolism and Cognition from the Perspective of Contemporary Hunter-Gatherer Research

These inferential problems are conspicuous to hunter-gatherer anthropologists for two reasons. First, as above, many contemporary foragers do not, for instance, habitually create structures as architecturally sophisticated as the V-shape joinery found at Kalambo Falls (Barham et al. 2023), nor as intricate as the ivory figurines of the Upper Palaeolithic (Conard 2009; Hahn 1986; Coolidge et al. 2012, though see Figure 1). The difficulties of interpreting of such materials are thus more immediately apparent. Second, foragers have faced discrimination (Woodburn 1997), often on grounds that their technologies and subsistence practices are atavistic, anachronistic or primitive (consider, e.g., Bagshawe 1925, p.120–21), a narrative that has had weighty material consequences (Layton 2001; Elkins 2022; Ndagala 1985). While preconceptions about living foragers have shifted, in considerations of past humans, similar tacit assumptions go unchecked, often unnoticed, making it especially important to explicitly interrogate the utility, perhaps sterility, of the material record in cognitive benchmarking.

This logical wrinkle — that modern humans need not leave any palpable material trace of their modernity — is interpretively important but difficult to demonstrate empirically. This is especially true in archaeological datasets which, by dint of uneven preservation, are normally incomplete. To better illustrate this issue, it is necessary to incorporate other forms of evidence, including ethnographic evidence, and to calibrate our expectations about past material complexity with data from modern populations for whom toolsets are comprehensively documented.

While certain researchers have made this precise point (e.g. Sterelny 2021b; Haidle 2016), such discussions have often focussed on the Australian continent (Hiscock 2007; Balme et al. 2009), particularly the indigenous people of Tasmania (Oswalt 1976; Haidle 2016) whose material culture is sometimes framed as an aberrant case of cultural loss (Henrich 2004). Moreover, discussions have been, by-and-large, non-quantitative (Haidle 2016) and often appear as asides or footnotes (Hiscock 2007; Sterelny 2021b; Kelly et al. 2023). There is clear need to illustrate the problem using a quantitative, data-driven approach.

This article explores three near-comprehensive material culture datasets from modern African foragers, representing a substantial proportion of contemporary African hunter-gatherer diversity. It investigates 1) how much evidence (assuming normal conditions of preservation) these modern human populations would leave of their artifactual repertoires, 2) whether there are processes, unrelated to cognition, that affect the likelihood of symbolic and other artefacts leaving an enduring signature.

While researchers have employed numerous lines of evidence to trace the emergence of complex cognition in the archaeological record (Table 1), including material transport (Wilkins et al. 2021), composite tool-production (Barham 2013; Coolidge et al. 2016) and other types of technological complexity (Sykes 2015; Wadley et al. 2020; Murray et al. 2020), evidence of prehistoric symbolism is frequently the most prominent (Sehasseh et al. 2021; Leder et al. 2021; Wilkins et al. 2021), and is often at the forefront of both academic discourse (McBrearty 2013;

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Mithen 2014; Klein 2017; Tattersall 2017a; Hoffmann et al. 2018; White et al. 2020; Pomeroy et al. 2020; Baquedano et al. 2023; Kelly et al. 2023; Wadley 2021) and popular accounts (Harari et al. 2020; Harari 2014). For ease of coding, analysis and discussion, therefore, the present investigation focusses primarily on 'symbolic evidence', broadly defined (Section 8). Despite this focus, current conclusions are generalisable to other categories of evidence also.

Researchers also differ in whether they attribute purported cognitive differences primarily to soma, culture or both. Some directly invoke genetic/neural differences, 'novel gene constellations' (Klein 2019, 179) or differences in capacity or potential (Mellars 2010; Mithen 2013; Wynn et al. 2016; Klein 2017, 2019), some invoke mixed models involving both cultural and somatic change (Kelly et al. 2023; Wadley 2013, 2021; Conard 2010; Knight 2010), and some prefer purely cultural evolutionary models which make no strong claims about genes, innate capacities or brains (Sterelny 2017; Sutton 2020). More attention is paid, throughout, to the interpretive problems inherent in the first two categories of model, although consideration is given, in Section 14, to pure cultural evolution models also.

The findings presented here demonstrate, empirically, that complex cognition *does not* necessitate extensive symbolic material culture, and that certain schema for identifying behavioural modernity (intrinsic or otherwise) would risk excluding contemporary humans. Moreover, results highlight the primacy of extra-genetic factors, including ecology, demography, artefact function and residential mobility, and the limitations each place on artefact repertoire-size and material selection (see Torrence and Bailey 1983; Shott 1986; Collard et al. 2005; Collard et al. 2011; Henrich 2004; Sterelny 2021a). Drawing on these data, I emphasise the difficulties of using past material culture, especially symbolic material culture, as an evolutionary yardstick, and the associated risk of falsely inferring that past humans who did not leave certain types of enduring evidence also lacked certain cognitive capacities.

6. Three forager datasets: The Hadza, the Mbuti and the G//ana

Although many populations around the world subsist by hunting and gathering (Lee and Daly 1999), holistic material culture datasets have been collated for a smaller number. The data used here were drawn from ethnographic accounts of material culture among three sub-Saharan African foragers, the Botswanan G//ana (Tanaka 1979), the Congolese Mbuti (Tanno 1981) and the Tanzanian Hadza (Woodburn 1970; Smith 1977; Marlowe 2010; Skaanes 2015). The author's field research is with the Hadza (Stibbard-Hawkes et al. 2018; 2020; 2022), and I augmented Hadza data with first-hand observation. As with any contemporary human population, all three groups in this study have complex systems of cosmological belief (Skaanes 2015; Ichikawa 1998; Solomon 1997; Stagnaro, Stibbard-Hawkes, and Apicella 2022), myths, oral histories (Osaki 2001; Kohl-Larsen 1956), rituals (Turnbull 2015; Skaanes 2015; Bundo 2001) and musical traditions (Nurse 1972; Marlowe 2010; Bundo 2001). Each have fully recursive languages which are phonologically and syntactically complex (e.g., Sands and Güldemann 2009; Vossen 2013).

These populations were chosen for three reasons. First, records of material culture were of a consistent high quality and sources were comprehensive in description of artefact function and material. Two sources (Tanaka 1979; Tanno 1981) were by members of the same research group,

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and so coded similarly. Second, the three study populations are from different parts of Africa, East (Hadza), South-West (G//ana) and Central (Mbuti) and represent all major regions where there exist well-described contemporary foragers. Third, the study populations represent at least two important ecotypes: The Hadza and the G//ana both have traditionally lived in savannah bushland environments, and the Mbuti in rainforest environments. Fourth, there exists little uncontested (Sands and Güldemann 2009) evidence for a close linguistic or phylogenetic link between the three groups, and each are from different parts of the continent with no recent history of interaction, minimising the impact of ancestral (i.e., Galton's Problem) and spatial autocorrelation. As our species' origins are in Africa, and as discussions of the 'human revolution' have sometimes concentrated on differences between the archaeological records of sub-Saharan Africa and Europe (e.g. see McBrearty and Brooks 2000; Mellars 2005; McBrearty 2007), data from contemporary foragers living in two important African ecologies are apposite.

This dataset included 256 artefacts, 90 from the Hadza, 97 from the Mbuti and 69 from the G//ana, comprising 362 discrete components, made from 48 distinct materials. The majority of artefacts (190) had no components attained from trade, while a minority (65) included traded materials. As technologies may be regularly invented and lost, complete repertoires are probably impossible, although these inventories are as close to comprehensive as any that exist.

Today, subsistence patterns are changing. The G//ana have largely abandoned traditional foraging practices (Osaki 2001). The Hadza are presently undergoing a rapid shift towards mixed subsistence (Pollom et al. 2021; Stibbard-Hawkes and Apicella 2022). Many Mbuti continue to hunt with nets, although regularly supplement their diets with food attained from neighbouring farmers, of whom there are an increasing number (Terashima and Ichikawa 2003). When study data were collected, however, each subsisted primarily through hunting and gathering.

Most bush-living Hadza before the early 2000s attained more than 90% of their calories through foraging. Accounts of Hadza material culture have been remarkably consistent in sources dating back to the early 1900s (see Marlowe 2010), as have reports of Hadza subsistence practices and demography (Marlowe 2010; Blurton Jones 2016). Among the G//ana there were reports, from the mid-to-late 1970s, of permanent G//ana 'basecamps' where people practiced mixed foraging alongside minor seasonal horticulture and kept livestock (Cashdan 1984). However, between 1966-1974, when study data were collected (Tanaka 1979), horses had not been widely adopted (Osaki 2001), people subsisted largely by foraging and moved residences frequently (Tanaka 1979). For the Mbuti, by 1974, when present data were collected (Tanno 1981), though there was little wage labour, itinerant traders visited most camps (Hart 1978) and traded crops, iron and tobacco for foraged goods. This intensified hunting, although did not otherwise impact hunting and foraging techniques or cause other documented technological change (Hart 1978).

None of these populations have historically been isolated, and all have traded and interacted with neighbouring farmers and pastoralists for as long as there are records (e.g., Marlowe 2010; Osaki 2001; Terashima and Ichikawa 2003). In certain tools, traded materials like iron and plastics have replaced traditional media like wood and stone. There are also some instances of minor technological exchange between these populations and their neighbours (Tanno 1981; Nurse 1972). I highlight and account for these patterns when relevant.

7. Tool Component Materials and Taphonomic Signatures

To investigate whether a particular tool would leave any archaeologically visible trace, it was first necessary to separate each tool into its component materials, and then code each material based on its potential to leave any enduring evidence. I name this variable 'taphonomic signature' — 'taphonomy' being the study of processes which affect the preservation and recovery of organic, or artefactual (Behrensmeyer et al. 2018) remains.

Tool material coding was primarily based on direct ethnographic descriptions. These had, in most cases (Marlowe 2010; Smith 1977; Tanaka 1979; Tanno 1981), already been tabulated by the ethnographer. In a minority of cases the presence of a particular material was inferred but not documented. For example, many Hadza leather items are stitched with bark thread, but this was sometimes (e.g., knife sheaths) not mentioned. In such cases, the material was recorded but coded as 'inferred'. Such materials were only listed when there was good evidence, and inferred materials were included in the final analysis. One item, a Hadza ritual cloak, though probably made of leather, was excluded from analysis as there was insufficient textual evidence to support this inference.

To account for materials only available through trade, I created a 'traded' variable. Materials were coded as 'traded' where specified by ethnographic accounts or where there was no ethnographically recorded way for those materials to be otherwise acquired (e.g. rubber, plastic, all metals).

For each material, I also coded taphonomic signature as a factor variable. Most plant-derived materials (e.g., wood, bark, fruit shells, seeds, leaves) and processed plant derivatives (e.g., rope, fibre) were coded as having a 'weak' taphonomic signature. So too were most animal by-products (e.g., fur, fat, wax, cocoons). Metals (iron, brass, copper, steel), plastics and synthetic rubbers were coded as having a 'strong' taphonomic signature, as were stone and bone. Shell and horn were an edge case. Although the outer keratinous sheaths of both tortoise shell and most ungulate horns are prone to decomposition (e.g., see O'Connor et al. 2015), the inner bone is not, and ethnographic sources did not make the distinction. I opted to code both horn and tortoise shell as having a strong signature, preferring to overestimate preservation probability. A minority of materials more fragile than bone but not prone to bacterial decomposition (e.g., eggshells, gastropod shells), were initially coded as having a moderate taphonomic signature. As there were few materials of this type, I collapsed moderate and strong to create a binary variable for analysis.

Codings were based on material only and do not account for depositional environment. Except in rare conditions (e.g. anaerobic marsh, permafrost, desert), post-depositional processes tend to reduce information. Given the correct conditions of preservation, even those artefacts coded here as having a 'weak' taphonomic signature may leave long-lasting traces (e.g., Thieme 1997; d'Errico et al. 2012; Wadley et al. 2020; Barham et al. 2023). However, such conditions are rare and, though taphonomic processes do not cause information loss at a consistent rate (Surovell et al. 2009), preservation probability decreases at greater time depths (Langley et al. 2008, 2011).

The dataset included >45 distinct materials, too many for meaningful statistical analysis. Therefore, to investigate material selection, I collapsed component materials into three categories: plant-derived (e.g. bark, fruit, stems, wood, seeds), animal-derived (e.g. bone, hide,

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horn, shells, cocoons) or inorganic (e.g. stone, metal, glass, plastics). Only four materials proved difficult to categorise: fungi, coded as 'plant-derived'; cloth, coded as 'plant-derived'; ash, coded as inorganic (see Karkanas 2021, for discussion of ash taphonomy); and rubber, today often synthetic, so coded as 'inorganic'. Annotated R code for category conversions is provided in the ESM.

8.Symbolism and Artefact Function

I also created a binary variable with the purpose of capturing whether a specific artefact would, by certain schema (e.g., Mithen 2014; Klein 2017), constitute evidence for complex cognition. This was not straightforward as even those scholars who seek to employ artifactual data in the study of past cognition recognise that inferring cognitive capacities from artefacts is 'notoriously tricky' (d'Errico and Henshilwood 2011, p.56) and often 'more art than science' (Coolidge et al. 2022, p.1). Evidential criteria vary between authors (Table 1) and definitions are fluid (Stringer 2002). Some authors employ broad definitions of 'modern cognition', which include complex exchange networks, technological diversification and hunting strategies (Davidson 2010; Ames et al. 2013). Others restrict definitions to symbolic evidence, broadly construed, including ochre-use, and decorative modifications such as polishing (e.g., d'Errico and Henshilwood 2011). Others employ an even narrower definition. Mithen (2014) discounts ochre-use. Klein (2017) limits evidence to 'unambiguous symbolic artefacts' including 'carefully cut, carved and ground' shell beads, and representational art, discounting much earlier symbolic evidence (e.g. ochre fragments; 'perforated shells').

Here, I chose to focus on evidence for symbolism, broadly construed. This is for two reasons. First, symbolic evidence is often highlighted by science communicators (Kurzgesagt 2016; Harari et al. 2020) and still garners extensive research attention (Vyshedskiy 2019; Leder et al. 2021; Kelly et al. 2023) as 'the *sine qua non* of modern human cognitive capability' (McBrearty 2013, p.13). Second, this simple binary variable clearly illustrates the mismatch between actual toolsets and enduring evidence, and the associated risk of false negative errors. Although symbolism makes a useful focal point for analysis and discussion, however, present inferences also apply to other diagnostic criteria with bases in material evidence (see Table 1).

I coded each artefact in the sample as 'symbolic evidence' when that artefact was either ornamented/decorated, was used for personal adornment or music-making, or had some other non-utilitarian function or modification. This included all musical instruments, toys, dyes and pigments, practical items with non-functional decorations (e.g. scored arrows, decorated bows), dolls, beads, jewellery (e.g., necklaces, rings), alongside as items of clothing which served no protective, thermoregulatory or clear utilitarian function (e.g., headbands, decorative belts). Clothing items with a practical purpose and no recorded additional decorative modification were excluded, as were most undecorated subsistence tools, storage containers, utensils etc.

Importantly, this variable quantifies whether an item would constitute *evidence* of symbolism, recognisable to a naive observer. It does not represent an artefact's actual symbolic function. Subsistence items without decorative modification are frequently replete with symbolic meaning (Wiessner 1983; González-Ruibal et al. 2011; Barham and Everett 2021). However, such information is unrecoverable without context. It may be, for example, that the Lomekwian or Oldowan lithics had important symbolic functions, although any such meaning is lost to time.

Conversely, the link between symbolic evidence and cognition has, itself, been both contested and debated (Mithen 2014; Shea 2011b; Stringer 2002). The inferential utility of ochre has been dismissed by numerous scholars (Sterelny 2011; Mithen 2014). And though artefacts have been linked by some to grammatical and linguistic ability (Klein 2017; Tattersall 2017b; Stout et al. 2021), others have highlighted the attendant inferential risks and pitfalls of trying to infer syntax or language skills from material representations (Botha 2008, 2010; Sterelny 2014; Henshilwood and Dubreuil 2011). Often, sophisticated artefacts need not necessitate sophisticated cognition *at all* (Sterelny 2014) and may be explicable through simple decision-rules (Walsh et al. 2013) and/or sensory stimulation/exploitation (*sensu* Verpooten and Nelissen 2010).

Moreover, the decision to define all artefacts without a definite utilitarian/social function as symbolic, especially, may yield false positives. Toys, for instance, often have pedagogical value (Riede et al. 2023; Lew-Levy et al. 2022), and for example miniaturised version of adult tools (Lew-Levy et al. 2022), such as the small hunting bows given to Hadza children (Marlowe 2010) have an explicitly educational purpose. Conversely, children often create art and representational media (Skaanes 2015). In cases of doubt I coded against the direction of the study's thesis, employing a broad operational definition of symbolism. As such, present categorisations probably overestimate the extent of symbolic evidence.

To explore whether certain types of tool were more likely to leave a taphonomic signature than others, I also coded tools by their function. These codings were based on ethnographic description and, for some Hadza artefacts, personal observation or discussion with other researchers (Blurton Jones, pers comm). Each tool could take up to three functions, although the majority (204/256) had only one. The resulting dataset included >25 unique tool functions, too many for useful analysis. These were collapsed into nine categories; 1) Tools used in the preparation/modification of other materials (e.g., hammers, awls, anvils, needles); 2) Storage/transport tools (e.g., containers, bags, slings); 3) Ritual artefacts and items of personal adornment; 4) Tools for play or leisure (e.g., instruments, toys); 5) Tools used in grooming, hygiene or medicine; 6) Items of furniture or shelter; 7) Foraging tools (e.g. arrows, digging sticks); 8) Cooking, eating and food-preparation tools; 9) Items of clothing or protection.

9.Statistical Analysis Strategy and Outliers

I statistically explored the influence of several predictors (population; symbolic evidence; artefact function; inclusion of traded materials) on 1) probability of artefacts containing enduring materials; 2) material type. The first set of models took taphonomic signature as the outcome, with trade, population, artefact function and 'symbolism' as predictors. As the taphonomic signature variable was coded as a binary, I used binomial regression models for these analyses. Because 'symbolism' and artefact function variables contained overlapping information - for example, all items of personal adornment were also classified as symbolic - I substituted these two variables in separate analyses. The second set of categorical models took material-type as the outcome, with trade and population as predictors. As material type was a three-factor categorical variable, I used a multinomial model for this analysis. Analyses were conducted in R and STAN using the Bayesian Regression Models (BRMs) package. I set random/varying effects at the population level, as information pooling typically results in better out-of-sample predictive accuracy. Bayesian methods were chosen as, though computationally expensive, and less widely used than their frequentist counterparts, they allow for more intuitive quantification, interpretation and visualisation of uncertainty in model outputs.

Do note, however, that this analysis uses population-wide tool repertories, and does not account for frequency of production. Thus, while the model outputs reported in Tables 2 and 4 are sufficient to provide broad inferences about population-level patterns, they cannot replicate the fidelity of, e.g., a site-level analysis of refuse production (see O'Connell et al. 1991).
Two artefacts caused Pareto K errors in leave-one-out [LOO] cross validation (i.e., disproportionately biased estimates). These were tyre sandals and clay pots. Clay pots aren't recorded for all populations, have a strong taphonomic signature and yet are untraded. As clay is an important material with a deep history, I chose not to exclude them. Tyre sandals are a rare clothing item that uses a traded material, has a strong taphonomic signature and only appear in a single population (Hadza). These did represent a genuine outlier with potential to bias estimates and were excluded from the final analyses.
Although the statistics employed here are, themselves, sophisticated I present fitted estimates (probabilities) in text, which can be interpreted straightforwardly by readers unfamiliar with Bayesian methods. For ease of comprehension, I report and discuss pertinent results in text. For readers wanting more technical detail, a comprehensive reporting of results, including full model estimates, model definitions and model selection outputs is provided in the electronic supplementary material [ESM], alongside commented analysis scripts and tabulated study data.

10. Would Contemporary foragers Leave Enduring Evidence of Symbolism?

Contemporary foragers are just as cognitively sophisticated as any other contemporary population and the three groups in this study each have complex cosmologies, myths, norms, oral histories and fully recursive, syntactically and phonetically sophisticated languages. The first study aim is to assess how much, if any, enduring, recognisably symbolic material evidence would be left by these contemporary human populations.

None of the study populations produce artefacts as detailed as figurines/paintings from Upper Palaeolithic Europe (e.g., Conard 2010; Harari et al. 2020; Klein 2017; Tattersall 2017a). Although there is rock art in Hadza territory (Mabulla 2005), in >100 years of ethnography, there are no accounts of its production (Marlowe 2010). Similarly, there are no records of painting from Mbuti, although they do produce intricately decorated bark cloth (Tanno 1981; Figure 1) and numerous plant-based pigments, dyes and body-paints (Tanno 1981). There exists much ancient Kalahari rock art but, while there are records of other Kalahari foragers producing it (Solomon 1997), the G//ana traditionally do not (Tanaka 1979, 197). Though there are accounts of ochre-use among the !Kung as bridal face paint (Marshall 1976, 276–77), and the /Xam as a leather-tanning agent (Wadley 2005), a comprehensive search yielded no records of pigment-use among the Hadza or G//ana. Moreover, despite the availability of bone/ivory, no populations produce carved bone figurines.

Figure 1: *Top: Illustration of Mbuti bark-cloth (pongo), reprinted from Tanno (1981); Bottom: Photograph of a Hadza unfired clay doll (ha!anakwiko), reprinted from Skaanes (2015). Both could be interpreted as signifying a sophisticated capacity for abstract thought, but neither would leave any long-lasting material evidence under normal conditions of preservation.*

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Burial, especially with grave goods, often features in discussions of prehistoric cognition (e.g. see Sommer 1999; Sterelny 2014; Wadley 2021; Pomeroy et al. 2020). While, as elsewhere, death has important cosmological significance, there is little elaborate or symbolic burial. Though no descriptions of G//ana funerary practices were found (though see Wiessner 2009), there are accounts from the Hadza and Mbuti. Among both individuals may be left in their huts, which are pulled down over them (Turnbull 1976, Woodburn, 1982). Though deep holes aren't made, Hadza individuals may also be interred in a shallow hole or natural hollow (e.g., an anteater hole), sometimes covered in sticks or soil to deter hyenas (Woodburn 1982). Neither use extensive grave goods (Woodburn 1982), though people may be buried with water gourds or digging sticks (Woodburn 1982; Skaanes 2015). Possessions are alternatively shared out or discarded (Turnbull 1976; Skaanes 2015). The Hadza sometimes bury bodies facing a particular direction — facing a high mountain or the sunset (Woodburn 1982). They may be placed on their sides or back, though there is no further ritual positioning or disarticulation (Woodburn 1982). Neither the Hadza nor Mbuti practice funerary caching (*sensu* Pettitt 2018), and people are interred in the camp in which they died, which is typically abandoned. Graves are left unmarked (Woodburn 1982). Therefore, while a full exploration of mortuary taphonomy is beyond the scope of this paper, neither the Hadza or Mbuti are likely to leave extensive evidence of symbolic nor perhaps even deliberate burial.

However, while certain symbolic expressions associated with the Upper Palaeolithic do not occur, symbolic material culture is far from absent. Hadza children produce shaped, unfired clay dolls (Figure 1) and cloth dolls of wrapped, unmodified rock or wood, while the Mbuti, alongside habitual pigment use, also produce elaborate bark honey containers. Each population produces musical instruments of several types (Tanno 1981; Marlowe 2010), with and without traded materials. More, the Hadza have traditionally produced numerous necklaces with a therapeutic purpose (Woodburn 1970). So, despite relatively small sets of artefacts (69-97) each population produces some which would constitute symbolic evidence by the strictest (Klein 2017) definition. While wholly conceivable that a human population might not create any material symbolic expressions, the present data do not make this case. However, when considering those artefacts which would reliably leave long-lasting evidence, a different picture emerges.

10.1 Evidence of Symbolism Excluding Traded Materials

For any study artefact, the mean estimated probability that it contained at least one archaeologically visible component was approximately 1/3rd (mean p = 0.32, 90% HDCI = 0.27-0.37). This was predominantly consequence of materials attained through trade. Items with traded components were substantially more likely to have a moderate/strong taphonomic signature (mean p = 0.82, 90% HDCI = 0.75-0.90) than those without, a mean absolute probability increase of 67 percentage points. This is because, across populations, materials attained from trade were overwhelmingly likely to be inorganic in origin (mean p = 0.66, 0.82 and 0.84, for the Hadza, Mbuti and G//ana respectively) and overwhelmingly unlikely to be animal byproducts. In consequence, materials attained through trade were disproportionately hard-wearing and non-biodegradable; and were often acquired for this reason.

This is important. While non-traded materials are, by-and-large, similar to those available in Palaeolithic contexts (wood, stone, bone, leather and plant fibre), traded materials such as refined metals, glass and plastics are younger. To better leverage the current datasets as a model for

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ancient hunter-gatherer taphonomy, it is necessary to consider preservation probabilities for artefacts without traded components.

When traded materials are excluded, the mean estimated probability of any artefact containing archaeologically visible components is universally low (mean p Mbuti = 0.08; Hadza = 0.17, G//ana = 0.24). The majority of artefacts produced would be invisible under normal conditions of preservation. This was also broadly true of artefacts which might constitute evidence of symbolism (Table 4). Excluding the effects of trade, the mean probability of a symbolic artefact containing an archaeologically visible component was only 0.06 for the Mbuti (90% HDCI = 0.01-0.11) and 0.13 for the Hadza (90% HDCI = 0.04-0.22), though somewhat higher for the G//ana at p = 0.34 (90% HDCI = 0.11-0.56). The majority of archaeologically visible symbolic evidence was consequence of a single material — ostrich eggshell — and to better understand these results, it is useful to consider each artefact individually.

Table 3 displays all artefacts that constitute evidence of symbolism *and* contain materials with a moderate/strong taphonomic signature. When those containing traded materials are excluded (Table 3.1), a total of two Hadza artefacts meet both criteria; four G//ana artefacts and only one Mbuti artefact; seven in total. The shell fragments from the G//ana dancing rattle would be difficult to recognise as human-modified, leaving six.

Of these six, five incorporate beads. One incorporated bone beads, while four incorporated ostrich eggshell, a material not in contemporary use by the Hadza. Ostrich-shell beads appear early in the African archaeological record (McBrearty and Brooks 2000; d'Errico et al. 2012) and are frequently cited as evidence for cognitive change in the African Late Stone Age (Klein 2017). However, contemporary ethnographic accounts of eggshell bead-making show it to be an elaborate process, involving several discrete steps, five separate tools, and substantial time (Hitchcock 2012). Many steps are neither obvious nor straightforward. Rather than an inevitable consequence of advanced cognition, it constitutes an ecology-bound invention (Mayer et al. 2020) which can be both culturally transmitted and lost, as it has been today among the Hadza.

Nor is it inevitable that beads should be manufactured from enduring media like eggshell, bone (Table 3.1) or marine shell (e.g., Miller et al. 2018); the Hadza traditionally produced beads from organic media including twigs, tubers and acacia pods (Woodburn 1970) while the Mbuti use seeds (Tanno 1981). Further, bead-use is dependent on thread, traditionally made by chewing/rolling the ligament/sinew of a large animal among the Hadza (Marlowe 2010, 85) and G//ana (Hitchcock 2012) or weaving plant fibre as among the Mbuti (Tanno 1981). Thread-making is another complex multi-step process which can be culturally transmitted, and lost. Despite its deep history (d'Errico et al. 2012), such knowledge is neither obvious, inevitable nor inborn. Excluding beads, no G//ana or Hadza artefacts without traded components would leave long-lasting symbolic evidence.

The Mbuti would leave just one potentially enduring symbolic artefact without traded components; a ritual horn/trumpet. This may be made of elephant tusk or bongo horn but also traditionally of wood or bamboo (Kenrick 1996; Turnbull 2015). These horns are not produced in great quantities — typically one per settlement (Tanno 1981; Turnbull 2015). They are neither elaborately decorated (Turnbull 2015) nor heavily modified and may not be recognisably manmade. Moreover, although no sources provided detailed description, it is probable that where bongo horns are used, it is the biodegradable keratin sheath, not the inner bone. The phonic properties of the horn are more important than its component materials (Turnbull 2015) and wood is used more often than horn (Kenrick 1996). All else is perishable.

Each study population is the beneficiary of millennia of additional cumulative technological evolution (see Marlowe et al. 2005; d'Errico et al. 2012) alongside technological exchange with neighbouring populations (Tanno 1981; Nurse 1972). Despite this, under normal conditions of preservation, certain criteria to identify cognitive modernity in the archaeological record (Mithen 2013; Klein 2017) would probably disqualify the Mbuti. Discounting shell and bone beads, which are commonly alternatively manufactured from perishable media, the Hadza and G//ana would also represent a false negative. Some have dismissed the notion that symbolic activities 'might have been expressed... in non-enduring material without having been expressed in stone and bone' (Mithen 2013, p.223). Present results demonstrate that this can and does happen.

10.2 Could the exclusion of traded materials mask enduring evidence of symbolism?

This discussion has so far ignored symbolic artefacts containing traded components (Table 3.2) because most materials attained from trade were not available in the deep past yet are overwhelmingly inorganic, hard-wearing and long-lasting (Figure 2). Preservation probabilities for symbolic artefacts with traded components where 0.71 (90% HDCI = 0.5-0.94), 0.74 (90% HDCI = 0.61-0.88) and 0.94 (90% HDCI 0.87-1) for the Mbuti, Hadza, and G//ana respectively. While there is good reason for excluding them, their exclusion may mask symbolic artefacts that would otherwise include widely available yet enduring media like stone and bone. For example, many artefacts which previously incorporated flaked or worked stone (e.g. knives; spearheads; axes) now incorporate metals instead (Tanaka 1979). It is useful to consider these case by case. To that end, I list all 'symbolic' artefacts containing taphonomically visible traded materials in Table 3.2. and discuss each here.

Iron arrowheads are used by all study populations. Were iron not available, it is possible to manufacture arrowheads from stone instead (see O'Driscoll and Thompson 2018). However, arrows are also manufactured entirely using perishable media. Bows are not used by all contemporary hunter-gatherers (see Stibbard-Hawkes 2020, for review) and, once again, constitute a complex technological innovation which is not universal.

The majority of other artefacts in Table 3.2, especially from the Hadza, contain glass beads. While beads are often manufactured from enduring materials like shell, they are also commonly manufactured from perishable media, including twigs and seeds. The Hadza and the G//ana historically also wore traded metal jewellery (brass/iron earrings, rings, bracelets) though there are no further records of rings or earrings being manufactured from non-traded materials. Bracelets are alternatively manufactured from leather or fur by two study populations though, again, not from any long-lasting materials.

Traded	Material	Mean *p* Mbuti	90% CI	Mean *p* Hadza	90% CI	Mean *p* G//ana	90% CI
No	Animal	0.12	0.07-0.17	0.36	0.29-0.44	0.47	0.37-0.57
No	Mineral	0.04	0.02-0.07	0.08	0.05-0.12	0.09	0.04-0.14
No	Vegetable	0.84	0.79-0.89	0.56	0.48-0.63	0.45	0.35-0.54
Yes	Animal	0.02	0.01-0.04	0.04	0.01-0.08	0.05	0.01-0.1
Yes	Mineral	0.66	0.51-0.8	0.82	0.73-0.9	0.84	0.74-0.92
Yes	Vegetable	0.32	0.19-0.47	0.14	0.08-0.22	0.11	0.05-0.2

Table 2 Mean fitted probabilities with 90 percent credibility intervals for plant-derived, animal-derived and inorganic materials with population and trade as predictors.

Table #	Artifact	Population	Material 1	Material 2	Material 3	Material 4	Material 5

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3.1 No Traded Materials							
	Bone Beads	Hadza	Bone (Baboon Knuckles)				
	Eggshell beads	Hadza	Eggshell (Ostrich)				
	Ostrich Shell Bead Head Band	G//ana	Eggshell (Ostrich)				
	Ostrich Eggshell Waist Band	G//ana	Eggshell (Ostrich)				
	Ostrich Eggshell Necklace	G//ana	Eggshell (Ostrich)				
	Dancing Rattle	G//ana	Insect Cocoon	Eggshell (Ostrich)			
	Bone Horn	Mbuti	Ivory or bongo horn				
3.2 Traded Materials							
	Fletched Iron Arrow	Hadza	Wood (Grewia)	Iron	Feather (Guinea Fowl)	Poison (Plant Extract)	Animal Ligament
			Resin Adhesive	Ash	Animal Fat	Leather	
	Ritual Ostrich Headdress	Hadza	Feather	Leather	Glass		
	Bells	Hadza	Metal	Leather			
	Glass Beads	Hadza	Glass				
	Plastic Beads	Hadza	Plastic				
	Bronze Ring	Hadza	Copper				
	Bracelet	Hadza	Brass				
	Ritual Gourd Pot	Hadza	Gourd	Plant Fibre	Glass	Animal Ligament	
	Musical Bow (Wire)	Hadza	Wood	Wire			
	Cloth Doll	Hadza	Cloth	Glass	Stone		
	Pangolin Scale Necklace	Hadza	Pangolin Scale	Leather	Glass		
	Tuber and Bead Necklace	Hadza	Glass	Leather			
	Bead Necklace	Hadza	Glass	Leather			
	Bead Armband	Hadza	Glass	Leather			
	Bead Headband	Hadza	Glass	Leather			
	Iron Arrow	G//ana	Wood	Iron			
	Iron Earring	G//ana	Iron				
	Musical Bow (Wire)	G//ana	Wood	Wire			
	Finger Piano	G//ana	Wood	Wire			
	Giraffe Tail Violin	G//ana	Wood	Wire	Leather		
	Tin Guitar	G//ana	Wood	Wire	Tin		
	Iron Arrow	Mbuti	Wood Raphia spp.	Poison (Plant Extract)	Leaf Fletching	Iron	Resin Adhesive
	Finger Piano	Mbuti	Wood	Wire			
	Ankle Bells	Mbuti	Metal				

Table 3: *All artefacts which constitute evidence of symbolism and contain at least one material with a moderate or strong taphonomic signature. Artefacts without traded materials first, artefacts with traded materials second.*

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Model #	Traded	Function	Mean *p* Mbuti	90% CI	Mean *p* Hadza	90% CI	Mean *p* G//ana	90% CI
4.1								
	No		0.08	0.03-0.13	0.17	0.1-0.25	0.24	0.15-0.34
	Yes		0.80	0.65-0.94	0.76	0.65-0.88	0.94	0.85-1
4.2								
	No	Clothing/Protection	0.01	0-0.03	0.01	0-0.02	0.02	0-0.05
	No	Storage/Transport	0.02	0-0.05	0.08	0-0.18	0.10	0-0.22
	No	Furniture/Shelter	0.03	0-0.07	0.05	0-0.13	0.08	0-0.19
	No	Foraging	0.05	0-0.11	0.08	0.01-0.15	0.16	0.02-0.29
	No	Ritual/Adornment	0.05	0-0.11	0.25	0.07-0.43	0.50	0.16-0.83
	No	Play/Leisure	0.06	0-0.13	0.06	0-0.11	0.15	0.01-0.3
	No	Grooming/Hygiene/Medicinal	0.08	0-0.18	0.18	0-0.4	0.21	0-0.51
	No	Cooking/Consumption	0.13	0.02-0.24	0.30	0.1-0.51	0.30	0.13-0.47
	No	Manufacture	0.17	0.03-0.3	0.34	0.14-0.54	0.41	0.17-0.66
	Yes	Clothing/Protection	0.32	0-0.7	0.19	0-0.39	0.44	0-0.86
	Yes	Furniture/Shelter	0.52	0.07-0.93	0.51	0.1-0.94	0.66	0.22-1
	Yes	Storage/Transport	0.52	0.19-0.87	0.67	0.36-0.97	0.79	0.53-1
	Yes	Ritual/Adornment	0.71	0.39-0.98	0.90	0.82-0.99	0.97	0.93-1
	Yes	Grooming/Hygiene/Medicinal	0.73	0.35-1	0.80	0.54-1	0.84	0.56-1
	Yes	Foraging	0.76	0.54-0.96	0.71	0.49-0.93	0.89	0.76-1
	Yes	Play/Leisure	0.78	0.57-0.98	0.60	0.29-0.9	0.87	0.73-1
	Yes	Cooking/Consumption	0.90	0.79-0.99	0.92	0.85-0.99	0.95	0.9-1
	Yes	Manufacture	0.92	0.83-1	0.93	0.87-0.99	0.97	0.92-1
4.3								
	No	Symbolic Signature	0.06	0.01-0.11	0.13	0.04-0.22	0.34	0.11-0.56
	No	No Symbolic Signature	0.10	0.03-0.16	0.19	0.1-0.27	0.22	0.13-0.32
	Yes	Symbolic Signature	0.71	0.5-0.94	0.74	0.61-0.88	0.94	0.87-1
	Yes	No Symbolic Signature	0.82	0.7-0.96	0.82	0.7-0.94	0.92	0.84-1

***Table 4:** Mean posterior probabilities with 90 percent credibility intervals for artefact containing at least one component material with a moderate or strong taphonomic signature. All are varying effect models with population as a grouping variable. Model 1 includes trade as a predictor, model 2 includes trade and all nine function variables, model 3 includes trade and symbolism.*

The Hadza manufacture cloth children's dolls (Woodburn 1970), which sometimes incorporate cloth-wrapped rocks. However, the rocks are largely unmodified so not recognisable as human artefacts without their cloth covers. Moreover, they are alternatively made with wood.

The remaining artefacts in Table 3.2 are either instruments or incorporate metal bells. Bells are manufactured by the Mbuti from wood though no records of non-traded bells exist for the two other populations. The G//ana manufacture rattles with eggshell fragments and the Hadza using seeds, which are perishable. Finger pianos are not made without metal, and are probably cultural borrowings (Tanno 1981), as are most wire string instruments (Nurse 1972, but see Padilla-Iglesias et al. 2022). There is no record of string instruments being produced from non-traded materials, although there are reports of Hadza hunting bows, manufactured from wood and sinew, being played as instruments (Woodburn 1970).

Thus, while traded materials, including metals, have replaced traditional media like bone and stone in several of the artefacts in the present sample, it is usually in tools used in foraging, manufacture and food processing, and not items with a symbolic function. Alternatives to traded media are largely organic and ephemeral. More, those alternatives which are not ephemeral are often ecologically bounded (ostrich eggshell; marine shell) and/or difficult to work with.

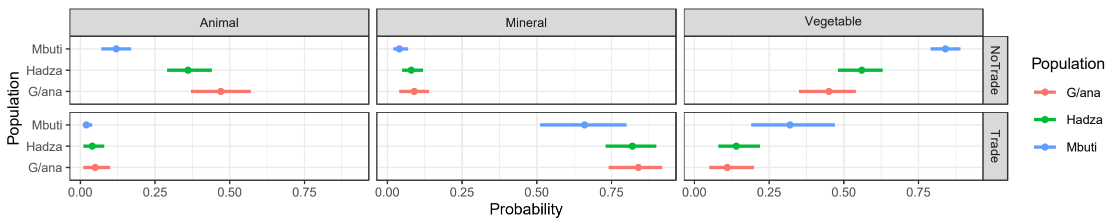

Figure 2: *Bar plots showing fitted mean probabilities and 90% CIs for each of the three study populations of using animal-derived, inorganic and plant-derived tool components. Untraded components above, traded components below.*

11 Is there Population-Level Variability independent of Differences in Cognitive Capacity?

Several authors (Shea 2011b; Hopkinson 2011; Haidle 2016; Scerri and Will 2023) have argued that inter-population behavioural variability and ecological flexibility, rather than cognitive change, are sufficient to explain many differences in past material. Many highlight that population-level differences in artifactual records are rational responses to varying subsistence environments (see O'Connell 1995; Shea 2011a; Collard et al. 2011). Thus, the second study aim was to investigate potential sources of variation in material use and preservation probability, causally independent of capacity. Results highlight several: ecology, mobility, cultural evolution.

First, there is clear statistical evidence for population-level differences in material selection. While all made comparable use of inorganic materials, when traded materials were excluded, the Mbuti used substantially more plant-derived materials and fewer animal-derived materials than the Hadza and G//ana (Table 2). These differences were statistically real and large (Figure 2). Although some variation results from culturally acquired knowledge, much is probably consequence of material availability. The Mbuti inhabit equatorial rainforest (Tanno 1981), where plant-derived materials are abundant. Ecological differences are often invoked to account for differences in prehistoric material culture (see, e.g., Brumm 2010; Blinkhorn et al. 2022; Scerri et al. 2022). Present findings highlight the primacy of ecology in shaping the material record.

The Hadza and G//ana both traditionally occupy savannah bushland (Tanaka 1979; Blurton Jones 2016) and it is unsurprising that both were more similar to each other in material use than to the

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Mbuti. Hadza artefacts had a higher mean probability of incorporating plant-derived materials than G//ana artefacts and a lower mean probability of incorporating animal-derived materials. Although there was significant overlap between population distributions (Figure 2), it was more plausible that data were created by different material selection processes than identical ones. This may, again, result from material availability. However, as many artefacts recorded only among the G//ana (e.g. feather balls; noisemakers; fire fans; straws; snares) are made from materials used by the Hadza, and vice versa (e.g. gambling chips; skipping ropes; clay dolls), knowledge-transmission probably has substantial influence.

There are additional processes which probably also impact material selection, but couldn't be statistically investigated here. Cultural evolutionary dynamics including demography (see Powell et al. 2009), population history (see Gray and Watts 2017), network structures (Sterelny 2021a), cultural exchange (*sensu* Granito et al. 2019) and cumulative innovation (Dean et al. 2014) probably play an important role. Residential movement also appears significant. All populations in this study are/were traditionally residentially mobile, although the Hadza more-so than the G//ana (Cashdan 1984). Mobility limits the number of artefacts that may be easily transported and creates trade-offs in material selection (Tanaka 1979, p.197). The most enduring naturally occurring materials, stone and bone, are among the densest and heaviest so will be preferred only when their utility compensates for their weight. Consequently sedentary populations, e.g. those exploiting perennially available marine resources (Jeffrey and Lahr 2020; Singh and Glowacki 2022), or occupying productive, defensible or well-situated locations such as shelters (Langley et al. 2011), may be overrepresented in the archaeological record by dint of relaxed constraints on material selection. As the three populations considered here were each highly mobile, present data are insufficient to test hypothesis directly. Other authors have investigated ecological determinants of forager toolkit complexity and repertoire size (Torrence and Bailey 1983; Shott 1986; Collard et al. 2005; Collard et al. 2011) though further research would be valuable to explore the impact of mobility specifically on material selection.

12 Does Artefact Function Influence Preservation Probability?

Earlier evidence is often taken to imply earlier invention. For instance tools used in butchery and food processing (Lemorini et al. 2014) substantially predate artwork and personal adornment in the archaeological record. However, where there are differences in artefact preservation probability, the more enduring artefact will probabilistically yield earlier evidence, even where both are of similar antiquity. Less enduring artefact types will also be more ‘prone to flickering’ (Scerri and Will 2023). Thus, if artefact function influences preservation probability, it may systematically confound the relationship between antiquity of evidence and chronology of invention.

The present dataset afforded an opportunity to explore, directly, the influence of artefact function on preservation. Here, tool function substantially influenced the likelihood of tools containing enduring components. While estimates were wide, these trends were statistically real and models including tool function substantially outperformed those without in a LOO model selection (see ESM).

As before, for artefacts including traded components, the probability of having a moderate/strong taphonomic signature was universally high for all artefact function categories except clothing. Distributions were wide for certain categories (e.g., furniture/shelter) reflecting a category-specific paucity of information (e.g., few types of furniture/shelter incorporated traded components). There was substantial overlap in estimates between populations. Excluding traded components, most artefact types had very low probabilities of containing components with moderate/strong taphonomic signatures. Clothing was the least likely to contain enduring components, with population means centring on p = 0.01-0.02 (Table 4). Tools used for storage and transport, items of furniture/shelter, articles of play and leisure, foraging tools and grooming/hygiene tools each also had constantly low probabilities of containing enduring materials.

Only two artefact types — artefacts used in cooking/food-consumption, and tools used in raw-material preparation or tool-manufacture — had probabilities of containing enduring components above 0.1 across populations. This suggests that such utilitarian tools should be overrepresented in archaeological assemblages (as indeed they often are, see Lemorini et al. 2014), and should have an earlier occurrence in the archaeological record (as indeed they do, see Harmand et al. 2015). As before, preservation probabilities were higher for Hadza and G//ana artefacts than Mbuti artefacts.

Despite wide estimates, for two of three populations, ritual/ornamental artefacts were more likely to contain enduring materials than other artefact types. This trend did not apply to the Mbuti and was, again, primarily consequence of ostrich eggshell in Hadza and G//ana jewellery. This population difference in preservation probability, resulting from a single material, once again highlights that the sudden appearance of evidence for personal adornment in the African archaeological record (Klein 2017; Sehasseh et al. 2021) may simply indicate shifting material preferences (e.g., ochre/marine shell/eggshell), rather than underlying differences in cognition or any more profound technological change.

13 Alternatives to Evolutionary Change

The data presented here show that fully modern human populations do not inevitably create extensive or, indeed, any identifiably symbolic material culture from enduring media. Results demonstrate that such items are not a prerequisite for cognitive modernity and highlight the risks of interpreting certain artefacts — figurines, artwork, beads, and pigments (Watts et al. 2016; d'Errico et al. 2012; Brumm et al. 2021; Coolidge et al. 2012; Wadley 2016; Klein 2017) — as indicators of evolutionary change. Beyond considering shifting material preference, this discussion has not comprehensively addressed why such technologies were absent for most of our lineage's prehistory, then rapidly appeared and proliferated. This is because, although present data demonstrate the difficulties of inference from absent evidence, they provide fewer concrete answers. Moreover, the issue is complex, and better addressed elsewhere (Scerri and Will 2023). Yet several mechanisms merit brief consideration.

Changing mobility patterns provide one plausible alternative (Shott 1986, but see Collard et al. 2011). It is notable that many of those ethnographically documented hunter-gatherers who produce extensive symbolic material culture are sedentary or semi-sedentary populations, who store seasonally abundant resources such as acorns, or anadromous fish (Testart et al. 1982; Kelly

2013). Similarly, mobility and shelter have been highlighted as a potential explanation for the relative paucity of the early symbolic material record in parts of the Australian continent (Balme et al. 2009; Langley et al. 2011).

Relatedly, population density might play a causal role in technological change (Collard et al. 2005; Powell et al. 2009; Kline and Boyd 2010). Larger (Powell et al. 2009) or more interconnected (Sterelny 2020, 2021a) populations may decrease the risk of stochastic knowledge loss. Such mechanisms could explain the small toolkit of indigenous Tasmanians (Henrich 2004; Sterelny 2021a). Moreover, more innovators and denser social networks may also hasten innovation and information spread (Kline and Boyd 2010). This idea has been debated (d'Errico and Henshilwood 2011; Henrich et al. 2016), but may account for the patterning of prehistoric material culture in some contexts.

Yet the most straightforward and parsimonious alternative mechanism for prehistoric technological change is simple, mosaic cumulative culture (e.g., Tennie et al. 2009; Dean et al. 2014) alongside technological ratchets (Lombard 2016; Tennie et al. 2009). All contemporary technologies, from laptops to eating utensils, have been invented by cognitively modern humans. These technologies replicate and spread between minds through numerous cultural processes, which have been fruitfully mapped and modelled. Certain technologies may act as prerequisites, scaffolds or even selective forces for further innovation (Sterelny 2017; Sterelny and Hiscock 2024). Just as writing systems enabled the encoding and storage of knowledge in stone, papyrus and vellum, so too may the development of string have allowed innovations in bead-making. Innovations in the properties of certain iron oxides may precipitate painting; innovations in stone-working techniques may enable the creation of figurines. Certain innovations may require a critical mass before a specific tipping-point is reached (Scerri and Will 2023), giving the false impression of a revolution in cognitive capacity, but in no cases need these innovations necessitate genetic or somatic change. As this study highlights, it is not only possible, but probable that many antecedent technologies will leave little trace.

14 Purely Cultural Accounts of Cognitive Modernity

Many highlight the primacy of cultural evolutionary processes in cognitive change, and separate cognition from genetic evolution. For example, some (Tattersall 2017b; Sterelny 2016), though not all (Klein 2017) late/recent language origins models view language as a cultural innovation, which enables new modes of thought and artistic expression. Some view 'behavioural modernity' as grounded in extra-genetic innovation (Sterelny 2017, 2019) in the scaffolds of thought (e.g., Sterelny 2019; Sutton 2020); tools of labour organisation (Sterelny 2017) and memory (Sterelny 2019; Tribble and Keene 2011; Sutton 2020). Here, the mind is seen as 'extended' (Clark 2001; Sterelny 2017, 2019; Sutton 2020, Wynn et al, 2021) through social cognition and material technologies — 'maps, signs, trail markers, scripts, notation systems, labels, instruments' (Sterelny 2017, p.242) — allowing for definitions of cognitive sophistication which make no strong claims about innate capacities (Sterelny 2011, 2016, 2019). These models sidestep a host of inferential difficulties (Speth 2004; Shea 2011b), chronological complications (Sterelny 2014; Scerri and Will 2023) and apparent material-somatic mismatches (Sterelny

2021a) inherent in linking material change to the substrates of the brain. However, in inferring certain capacities from absence-to-presence shifts in the material record (Sterelny 2011, 2016), and in coopting the terminology of earlier models (Sterelny 2011), cultural accounts sometimes share difficulties with their antecedents.

Many cultural-evolution models still often leverage absence-presence shifts in the archaeological record of certain artefacts to infer the presence or absence of *other* capacities (Sterelny 2011, 2016, 2014, 2017; Tennie et al. 2017; Tattersall 2017a; Bolhuis et al. 2014) including behavioural modernity (Sterelny 2011, 2014), full language (Sterelny 2016; Tattersall 2017b) or complex social organisation and economic life (Sterelny 2014, 2020, 2021a). 'Zone of latent solutions' models, for instance, view technological change in terms of probabilistic processes like innovation and transmission (Tennie et al. 2017) but make second-order claims about the intrinsic capacities of extinct humans (see Sterelny 2020; Sterelny and Hiscock 2024). Even frameworks that infer one culturally acquired skillset through indirect evidence from another may encounter problems. For example, Sterelny (2016) leveraged four categories of material evidence, including 'manufacture, use, and social transmission of different technological suites' (p.182) to infer that that *Homo hidelbergensis* was 'unlikely to have anything approximating full language' (p.178) which probably appeared late. This paper highlights the absence of 'figurines or other objects made for non-utilitarian purposes', 'jewellery' and 'ochre' (p.179). While Sterelny (2016) integrates three other types of information, considers perishable media, and highlights the interpretive difficulties of symbolic evidence elsewhere (e.g., Sterelny 2011, 2014), he yet concludes 'it is likely that we would see... traces' (p.179). Here, the lessons of the current dataset — that living people may not create certain signs ideological life (*sensu* Sterelny 2014, 2016), or may create them without enduring media — remain relevant.

The second set of difficulties with purely cultural accounts are not interpretive but terminological. I see two primary issues. First, although terms like 'behaviourally modern' may be used in a purely cultural sense (Sterelny 2011, 2016, 2019), for readers from other disciplines they risk invoking the epistemic baggage — assumptions, associations and conclusions — of earlier models (Klein 2002; Bar-Yosef 2002; Mellars 2005, 2006), especially as the term 'modern' retains its original meaning elsewhere (Klein 2019). Additionally, though it is useful to consider technological and demographic tipping points (Sterelny 2019; Sterelny and Hiscock 2024) the term 'behavioural modernity' also inherits many attendant definitional difficulties as a threshold, trait-list or concept (Stringer 2002; Henshilwood and Marean 2003; Shea 2011b; Ames et al. 2013; Meneganzin and Currie 2022; Scerri and Will 2023). Even the word 'cognition', though usefully defined broadly (Clark 2001), may, to lay readers, be redolent of intrinsic capacities such as working memory (Coolidge et al. 2012), or neural connectivity (Wadley 2021). Last, even accepting equality capacity, discussions of 'behaviourally modern cultures' (Sterelny 2011, 2014, 2016), or cultural complexity (Sterelny 2021a) risk ranking or grading cultural differences. For instance, in considering that the earliest peoples of Australia must have possessed marine travel (Allen et al. 2008; Habgood and Franklin 2008), yet left relatively few enduring traces of material complexity, Sterelny (2011) suggests that 'Australians ceased to be modern after they arrived' (p.819). This example illustrates the problems with viewing material change as unidirectional and capacity-bound. However, it again places technology at the fore. The ancient Australians themselves may have queried the notion they were less modern than their forebears because they lacked boats.

Even discussion of cognitive ecologies (Sutton 2020; Tribble and Keene 2011), niches (Tribble and Keene 2011), or of past peoples living 'such different lives' (Sterelny 2019), may lead us to overemphasise cultural distinctions. Though technology is inarguably important, cultural boundaries are permeable and delineated more by language barriers, social network structure or exogamy rules and other associative proscriptions than by other innovations in the scaffolds of thought. Individuals in a foraging niche (see Sutton 2020, p.220) have no difficulty cooperating and collaborating across such boundaries, and may readily transition to other niches entirely, and back.

Theorists do recognise modern foragers as culturally complex (Sterelny 2014, 2021a). Sutton (2020) cautions against orthogenic reasoning. Henrich (2004) is clear that indigenous Tasmania experienced no devolution across cultural domains (p.203) accompanying technology loss. Moreover, terminologically choppy waters of this kind are not unique to cognitive archaeology (e.g., see Lavi et al. 2024). Yet in, e.g., defining 'cultural complexity' (Sterelny 2021a) in terms of either toolkits or the structure of social networks — and focussing primarily on these in considerations of certain populations (e.g., Oswalt 1976; McGrew 1987; Henrich 2004; Haidle 2016; Sterelny 2021a) — we miss that small populations, with small toolkits, may yet have rich social lives, complex belief systems and languages. In light of present evidence, there is cause for caution in advancing schema of cognitive change that would, when extended to other human populations — or their material traces — appear to create a hierarchy of culture forms, or classify some as more cognitively or behaviourally modern, complex, or otherwise differently graded than others.

15Limitations

While the material culture datasets analysed here are comprehensive, and represent most recorded contemporary hunter-gatherer material diversity across a whole continent, they still have important limitations.

First, the current study incorporates evidence from only three populations. Although datasets are thorough and represent two important ecologies, this study only captures a small proportion of global hunter-gatherer diversity (see Kelly 2013; Lee and Daly 1999). These data are sufficient to demonstrate that contemporary humans do not inevitably produce enduring symbolic artefacts. However, to statistically investigate broader patterns (e.g. see Collard et al. 2011; Collard et al. 2005; Shott 1986; Torrence and Bailey 1983), a larger dataset is needed.

Second, these datasets represent a 20th century snapshot of material culture over at most an 80-year-span. By contrast, although lacking comparable resolution, archaeological datasets represent a much larger scale of analysis. Many sites span millennia, and data are drawn from a considerably wider geographic area. It may yet be that modern humans are defined not by their universal use of enduring symbolic material culture, but by their propensity to probabilistically reinvent it, either due to some intrinsic (Klein 2019) or context-bound (Henshilwood and Dubreuil 2011) proclivity, or because it exists within a particular species' zone of latent solutions (see discussion by Tennie et al. 2016, 2017; Sterelny 2020; Sterelny and Hiscock 2024). Under this assumption, even were evidence for symbolism often absent, general cross-site temporal trends may still track species-level cognitive change.

This supposition, while logical, is unproven, difficult to test empirically and does not reflect historically recorded patterns of human technological evolution. Moreover, there are indications that extensive enduring symbolic evidence is *not* inevitable, even at greater timescales. The paucity, relative to the European record, of well-preserved early symbolic evidence from Wallacea and Sahul (but see Langley et al. 2019) despite at least 50-55,000 years of continuous modern human occupation (Habgood and Franklin 2008; Brumm and Moore 2005; O'Connell et al. 2018), probably 'mainly reflects the failure of early cultural expressions to be preserved and discovered' (Hiscock 2007, 121) and results from the fact that 'much of the ornamentation used by Australian Aboriginal people was made from perishable material' (Balme et al. 2009, p.65). This argument is not unassailable as there is increasing evidence of long-distance shell transport, ochre-use, and potentially ancient pictographic art (David et al. 2013; Langley et al. 2011; Langley et al. 2019). Yet, extra-genetic processes of cultural evolution — invention, horizontal/vertical transmission and cumulative change (e.g., Tennie et al. 2009; Dean et al. 2014) — still appear more parsimonious than models invoking some capacity shift or major cognitive sea change. Unfortunately, the present evidence, being narrowly bounded in time, cannot conclusively address this question.

16Conclusion: Reconsidering the link between material culture and cognition

Despite some limitations, the present analysis yields three findings that are important when linking material evidence to cognition in past populations.

First, these data reveal important taphonomic filters (Shea 2011b; Pascual-Garrido and Almeida-Warren 2021) in forager material culture. Many contemporary forager artefact sets are small, and the subset of those artefacts that would leave an archaeological signature under normal taphonomic conditions is smaller still. Many technologies, practices and artefacts commonly considered in discussions of past behavioural complexity — painting (Wynn et al. 2009; Aubert et al. 2019), elaborate burial (Sterelny 2016), pigment and dye production (Watts et al. 2016; Watts 2010) — are either wholly absent or, when they do appear, effectively traceless. When traded materials (e.g., plastic; metals; glass) are excluded, certain schema to detect cognitive modernity in prehistoric populations (Table 1) would probably discount one of the three contemporary populations in the present study. Except for certain types of bead, for which there are perishable alternatives, they would rule out all three.

Second, results show that artefact function influences preservation probability. Those utilitarian artefacts used in the processing/preparation of foods, raw materials, and/or other tools, are more likely to include hard-wearing, taphonomically visible components. This implies that such artefacts will be overrepresented in past hunter-gatherer assemblages also. For 2/3 populations, items of personal adornment are also more likely to contain long-lasting materials. This primarily results from a single material, ostrich eggshell, suggesting populations that habitually utilise this material will leave greater evidence of symbolic behaviour than those which don't. This is significant as, despite the research attention given to beadwork in discussions of cognitive evolution (Bar-Yosef 2002; Klein 2017; Kelly et al. 2023), for instance as 'especially compelling evidence for "symbolism"' (Klein 2019, 181), ostriches are an endemic species with a limited range, and the production of eggshell beads is neither a straightforward nor obvious innovation (Hitchcock 2012). Simple shifts in material preference may thus create the illusion of sudden and profound behavioural change.

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Third and finally, results show significant population-level differences in material use which create differences in artefact preservation probability. These do not stem from differences in cognition. Instead, they are consequence of ecological differences in material availability and probably other population-level processes also, including demography and cultural transmission dynamics (see Scerri and Will 2023), alongside practical constraints (see Collard et al. 2011), for instance regular residential movement (Shott 1986).

Revolutions in human behaviour and material culture are commonplace throughout history, independent of somatic evolution. Agriculture led to profound changes, not just in subsistence and technology (Larson et al. 2007; Stock and Pinhasi 2011), but also in population movement (e.g., Holden 2002), health and demography (Stock and Pinhasi 2011; Wells and Stock 2020). Innovations in military tactics and technologies have rewritten the cultural, technological and linguistic landscape of Eurasia numerous times over the past two millennia (e.g., Greene 1990; Allsen 2002). Innovations in manufacture and finance (Smith 1778) in the 18th century substantially changed patterns of trade, production and subsistence on a global scale, as did 20th century revolutions in information technology and communication (Leiner et al. 2009). Though these periods of revolution sometimes altered selective environments (Stock and Pinhasi 2011; Richerson, Boyd, and Henrich 2010), they did not result from neural, genetic or profound cognitive differences. Instead they were products of innovation and cultural transmission. Similarly, the spread of polished ostrich eggshell beads in Late Stone Age Africa (e.g., Klein 2017), and of ivory figurines in Upper Palaeolithic Europe (Hahn 1986; Conard 2009; Wynn et al. 2009; Klein 2017), rather than evidencing the appearance of modern cognition (sensu Bar-Yosef 2002; Sterelny 2011; Klein 2008), probably represent the invention and dissemination of these particular technologies. Where other evidence is lacking, it is parsimonious to interpret differences in material culture between both different human species and different *Homo sapiens* populations similarly.

This is important not only in interpreting the material record, but also from a meta-scientific perspective. Notions of technological and societal advancement have been erroneously used as justification for discrimination against forager populations (Woodburn 1997; Hennessey 2020). Many researchers have highlighted that by equating material culture with advancement, we replicate many of the assumptions of progressive unilinear/social evolutionism (Shea 2011b; Milks 2020) grounded in late 19th century thought (for reviews see Olusoga 2016 ch.10-12 and Mukherjee 2016, pt.1). This logic is less consequential when applied to past populations where it cannot influence policy (see McDowell 1984; Ndagala 1985). Yet there is cause for caution in advancing theories of population-level cognitive differences on the basis of material culture, lest we further perpetuate these notions. Though less prone to essentialism than somatic models, cultural models of cognitive evolution are not immune to orthogenetic language and reasoning either.

The data considered here do not provide substantial *positive* evidence concerning the timings and pace of human cognitive evolution. However, the current finding — that completely modern humans, benefiting from thousands of years of cumulative culture and technological exchange, would yet themselves leave scant material evidence — might prompt us to profitably reconsider our null hypothesis *in the absence* of definitive evidence, or in considering absence-presence transitions in the material record. The default ‘ancestral’ or ‘primitive’ null model has repeatedly led researchers to be surprised when complex technology appears early (Metcalfe 2023) or is associated with human species other than our own (Mellars 2010; Hoffmann et al. 2020). Researchers attributing cognitive sophistication to other human species (d’Errico 2003; Zilhão et al. 2010) or proposing gradual/mosaic chronologies (McBrearty and Brooks 2000; McBrearty

2013; Shea 2011b; Scerri and Will 2023), have often faced considerable pushback (Porr 2011; White et al. 2020; Mithen 2014; Schmidt et al. 2019; Mellars 2010).

Dialectics are important to the scientific process, and new discoveries and paradigms should be interrogated, yet it is notable that where consensuses have shifted, the net of cognitive sophistication has almost unfailingly broadened (McBrearty and Brooks 2000; d'Errico et al. 2003; d'Errico 2003; Langley et al. 2008; Zilhão et al. 2010; Sykes 2015; Barham et al. 2023). This pattern reoccurs often enough that we may induce some systemic fault with our default assumptions. An agnostic null model would have gone some way towards bringing expectations in line with the latent facts. We could still adopt one. Alternatively, given the influence of orthogenetic logic in Western scholarship (Kipling 1899; Bagshawe 1925; Jacques 1997; Olusoga 2016; Mukherjee 2016; Elkins 2022), and its capacity to create false intuitions (Speth 2004; Shea 2011b; Milks 2020), we might temper known inferential biases by adopting a 'derived' or 'cognitively modern' null: that, until proven otherwise, all members of at least our genus had comparable capacities.

In light of present findings, it appears more parsimonious, at least in the absence of other conclusive evidence, to interpret differences or shifts in material culture between past *Homo sapiens* populations (Speth 2004; Hopkinson 2011; Shea 2011b; d'Errico and Stringer 2011; Milks 2020), and indeed members of our genus, as resulting from extra-genetic processes. Likewise, we should be hesitant in inferring from the material record the absence of other important but traceless cognitive technologies (Sterelny 2016; Coolidge et al. 2016; Tattersall 2017a) such as language, either within or between species. Genetic or skeletal evidence may yet shed light on the origins of certain cognitive capacities (see Albessard-Ball and Balzeau 2018; Mounier, Noûs, and Balzeau 2020). However, the present findings highlight the risks of discounting perishable media (see Mithen 2013; Pascual-Garrido and Almeida-Warren 2021) and the difficulties of inferring symbolic thought and aspects of cognition from the presence and, especially, the absence of certain artefacts. Variation in the material culture of contemporary human populations, though often profound, does not seem to indicate profound differences in cognition, however defined (Sterelny 2019; Klein 2019), and certainly no differences in capacity. Instead, it reflects a host of independent causal processes; economic, ecological, demographic, pragmatic and cultural. We should reconsider the link between material culture and cognition in past populations also, and should abandon any litmus test for cognitive or behavioural modernity which would reliably exclude modern humans.

Data Availability and Supplementary Materials

A comprehensive reporting of results alongside data and R code for all analyses are available from: https://github.com/DStibbardHawkes/MaterialCultureESM

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Competing Interests Declaration

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