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

Duncan N. E. Stibbard-Hawkes

Department of Anthropology, Durham University, Durham, UK
duncan.stibbard-hawkes@durham.ac.uk

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Corresponding author:
Duncan N. E. Stibbard-Hawkes;
Email: duncan.stibbard-hawkes@durham.ac.uk

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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 palaeoanthropologists 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, although these groups are unequivocally behaviourally modern, they would leave scant long-lasting evidence of symbolic behaviour. Artefact sets are typically small, perhaps as a consequence of residential mobility. When traded materials are excluded, few artefacts have components with moderate–to–strong taphonomic signatures. The 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 among populations, which create important population-level variation in 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.

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 nonenduring material without having been expressed in bone and stone.
>
> — 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, Friederici, Chomsky, & Bolhuis, 2013) and leave little skeletal evidence (but see Albessard-Ball & Balzeau, 2018; Mounier, Noûs, & Balzeau, 2020), researchers have instead sought indirect evidence (Tattersall, 2017a) for the emergence of modern human cognition. For example, many interpret the proliferation (Kelly, Mackie, & Kandel, 2023) of sophisticated material culture ~70,000 (Bolhuis, Tattersall, Chomsky, & Berwick, 2014; Tattersall, 2017a) to 50,000 (Klein, 2017) years ago as a watershed moment in human evolution, indicating "cultural" (Conard, 2010) or "behavioural" (see Ames, Riel-Salvatore, & Collins, 2013; Mellars, 2005) modernity, the appearance of "fully-fledged" (Klein, 2017) recursive (Vyshedskiy, 2019) language, long-range temporal planning (Davidson, 2010) and travel (Davidson & Noble, 1992), a capacity for systematising (Baron-Cohen, 2020), abstract, symbolic (Klein, 2017), complex (Bolhuis et al., 2014) thought, perspective-taking (Henshilwood & Dubreuil, 2009), enhanced working memory, executive function (Coolidge, Wynn, & Overmann, 2012; Wynn & Coolidge, 2010; Wynn, Coolidge, & Bright, 2009), increased cognitive fluidity (Mithen, 2013), ritual (Watts, Chazan, & Wilkins, 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., Baquedano et al., 2023; Finlayson et al., 2012; Hardy et al., 2020; Hoffmann et al., 2018; Kozowyk, Soressi, Pomstra, & Langejans, 2017; Schmidt et al., 2019; Turk et al., 2018). For instance, the association of symbolic (Baquedano et al., 2023; Zilhão et al., 2010) and complex material culture (Hardy et al., 2020; Kozowyk et al., 2017) including artwork (Hoffmann et al., 2018) with Neanderthals

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has led, in recent years, to a revised consensus on Neanderthal cognition (Sykes, 2015; Zilhão et al., 2010) and greater recognition of their "shared humanity" (Breyl, 2021).

Although some have considered contemporary hunter–gatherers in discussions of cognitive evolution (Haidle, 2016; Killin & Pain, 2023; Shea, 2011b; 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, Buchanan, Morin, & Costopoulos, 2011; Henrich, 2004; Shott, 1986; Sterelny, 2021b; Sterelny & Hiscock, 2024). 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 multicomponent tools, often seen as a stage-post in human evolution (Barham, 2013; Sykes, 2015; Wadley, Hodgskiss, & Grant, 2009), have multiple centres of origin (Blinkhorn, 2019) dating to perhaps 500 ka and at least 280 ka in Africa (Sahle et al., 2013; Wilkins, Schoville, Brown, & Chazan, 2012) and at least 300 ka in 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 & 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, Harris, Oestmo, Martin, & Marean, 2020). Moreover, the creation of wooden structures with joinery dates to 476,000 ka (Barham et al., 2023).

Duncan N. E. Stibbard-Hawkes is an assistant professor of anthropology at Durham University. He holds a PhD in Evolutionary Anthropology from the University of Cambridge. Since 2012, he has been conducting research among the Hadza in northern Tanzania, who have traditionally subsisted by hunting and gathering. His work explores foraging, food-sharing, and the use and abuse of theory in hunter–gatherer research. Alongside research into methodological best practice, he has sought to critically tease apart foundational truths and myths in the study of forager food-sharing, gendered labour divisions, social preference, signalling, nutrition, health, and political organisation.

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, for example, 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 & Backwell, 2016; Vanhaeren, Wadley, & d'Errico, 2019). Nonperforated shells from Israel also with a proposed symbolic function date to between 240 and 160 ka (Mayer et al., 2020). Moreover, one temporally isolated carved mussel shell was found in *H. 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, whereas the collection of nonfood seashells dates to at least 90 ka in South Africa (Marean, 2010) and the Levant (Bar-Yosef Mayer, Vandermeersch, & Bar-Yosef, 2009).

Although complex and symbolic artefacts exist from great time depths (Barham et al., 2023; Joordens et al., 2015; McBrearty & Brooks, 2000), many scholars contend that 70–50 ka was yet characterised by rapid transformation, innovation, and change in the artefactual record (Kelly et al., 2023). From 50 ka and beyond, there are numerous examples of "indisputable art and personal ornaments" (Klein, 2017, p. 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 at 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 evidence, especially after 70 ka (see Kelly et al., 2023), has led many to favour a "recent" origin of modern human behaviour (Klein, 2019; Mellars, 2010). The

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Table 1. Noncomprehensive table of proposed criteria 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

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, 2010)
Ritual behaviour	Pigment use and transport	Watts et al. (2016)
	Crystal transport	Wilkins et al. (2021)
Complex communication systems	Personal ornaments; beadwork	Vanhaeren, D'Errico, van Niekerk, Henshilwood, and Erasmus (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 and 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 (2013); Wadley et al. (2009)
	Grass bedding; bedding ash	Wadley et al. (2020)
Behavioural modernity	Compound tools; burials; colorants; adornment; engravings; figurines; instruments	Nowell (2013)

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 in 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" (Klein, 2017; Mellars, 2010), 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 & 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/neural differences or via culturally transmissible extrasomatic 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" (Bolhuis et al., 2014; Tattersall, 2017a) evolved alongside archaic *H. 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 *H. sapiens* and Neanderthals (Tattersall, 2017a), or between earlier and later *H. 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).

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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, Vandermuelen, & Casanave, 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." Although not all popular texts promote this view (Graeber & Wengrow, 2021; Sykes, 2020), 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 & Balzeau, 2018; Mounier et al., 2020). Many highlight earlier artefactual evidence of symbolic behaviour (McBrearty, 2013; McBrearty & Brooks, 2000), especially outside of Europe (McBrearty & Stringer, 2007). Evidence of symbolism associated with Neanderthals (e.g., Hoffmann et al., 2020; Nowell, 2013; Zilhão et al., 2010) – who diverged from *H. sapiens* 700–400 ka (see Stringer, 2016) – has fuelled phylogenetic arguments for early origins of symbolic capacity (see Leder et al., 2021; Mellars, 2010; Zilhão, 2007).

Some have questioned the extent to which specific artefacts actually do evidence linguistic ability or symbolic capacity (Botha, 2010; Kuhn & Stiner, 2007; Sterelny, 2011, 2014). Ochre, for instance may have prosaic and functional uses, for example as camouflage, insect repellent, an adhesive (Sterelny, 2011; Wadley, 2005), or a threat display (Kuhn & Stiner, 2007; Sterelny, 2011). Similarly, the link between material culture and certain aspects of syntactic or linguistic ability is not concrete (Botha, 2010; Henshilwood & Dubreuil, 2011; 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 & Dubreuil, 2011).

Others have highlighted more general difficulties in reading the material record (Ames et al., 2013; Dibble et al., 2017; Haidle, 2016; Scerri & Will, 2023; Shea, 2011b; Speth, 2004; Zilhão et al., 2010), including the risks of ignoring differences in preservation environments and material choices (Langley, Clarkson, & Ulm, 2011; Shea, 2011b), the risk of overattributing 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 & Almeida-Warren, 2021) and contended that complex perishable technologies substantially pre-date even the earliest lithic industries (Pascual-Garrido & 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; Henrich et al., 2016; Powell, Shennan, & Thomas, 2009; Scerri & Will, 2023; Sterelny, 2021a; but see Klein & Steele, 2013; Vaesen, Collard, Cosgrove, & Roebroeks, 2016). Others argue that differences in material culture should be conceptualised not as markers of changing cognition, but as responses to varying environments (d'Errico & Stringer, 2011; Hopkinson, 2011; Shea, 2011b) – although material variability has, itself, sometimes been used to chart cognitive evolution (see, e.g., discussion by Nowell & White, 2010; Shea, 2017; Tennie, Braun, Premo, & McPherron, 2016; Wadley, 2016). Several have pointed to the difficulties of defining cognitive and linguistic "modernity" (d'Errico, 2003; Shea, 2011b; Stringer, 2002) or otherwise critiqued the notion of behavioural modernity as an analytically useful concept (Ames et al., 2013; Scerri & Will, 2023; Shea, 2011b).

Despite continued discourse concerning recent origins theories (d'Errico et al., 2020; Klein, 2017; Scerri & Will, 2023), over the last decade, research consensus has leaned 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 more broadly (Sterelny, 2016, 2019) have become more widely accepted. Focus has also shifted to explorations of species-level differences (Wynn, Overmann, & Coolidge, 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 Hardy et al., 2020; Kozowyk et al., 2017; Schmidt et al., 2019). Neanderthal personal adornment (Finlayson et al., 2012), burial (Pomeroy et al., 2020), art (Hoffmann et al., 2018; White et al., 2020), nonsubsistence-related faunal assemblages (Baquedano et al., 2023), and musical instruments (Turk et al., 2018) are frequently used as evidence both for (Breyl, 2021; Hardy et al., 2020) and against (Schmidt et al., 2019; Wynn et al., 2016) Neanderthals possessing, for example, "symbolic thought" or "modern human" cognitive capacity. These recent debates have fruitfully challenged assumptions (Baquedano et al., 2023; Breyl, 2021) that Neanderthals had less advanced (see, e.g., Mithen, 2014; Speth, 2004) or substantively different (see, e.g., Wynn et al., 2016) cognitive capacities to modern *H. 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 & 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 (Henshilwood &

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Dubreuil, 2009; Klein, 2017; Mellars, 2005; Wadley, 2021) 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: That is, where "A" implies "B," it does not follow that "not A" implies "not B." In other words, although evidence of sophisticated material culture might provide positive evidence of cognitive sophistication (Finlayson et al., 2012; Haidle, 2016; Lombard & Haidle, 2012; 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, see, e.g., Botha, 2008, 2010; Sterelny, 2014), but is not a necessary condition of cognitive complexity (see Ames et al., 2013; Haidle, 2016; Hopkinson, 2011; Scerri & Will, 2023; Shea, 2011b; Speth, 2004, 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 (Kelly et al., 2023; Mellars, 2010; Shultz, Nelson, & Dunbar, 2012; Wadley, 2013). Bolhuis et al. (2014) highlight that "inference from the symbolic record… rests on evidence that is necessarily quite indirect" (p. 4), whereas 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, although alive to these difficulties, many continue to overinterpret the material record. Here, I describe three recurring 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 hypotheses about transitions in human minds or brains; and (3) the (null) assumption that, without positive evidence to the contrary, early *H. 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), although 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 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 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 & Chaminade, 2012; Stout, Chaminade, Apel, Shafti, & Faisal, 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 the four categories of evidence to infer that *Homo heidelbergensis* 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 artefactual evidence (Barham & Everett, 2021; Conard, 2015; Coolidge, Haidle, Lombard, & Wynn, 2016; Henshilwood & Dubreuil, 2011; Kelly et al., 2023; Muller, Clarkson, & Shipton, 2017; Stout et al., 2021; Wadley et al., 2020) in establishing a chronology for cognitive evolution, or in comparing human species (Leder et al., 2021; Schmidt et al., 2019; Sykes, 2015), 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

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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; Gilpin, Feldman, & Aoki, 2016; Horan, Bulte, & Shogren, 2005; Villa & Roebroeks, 2014). It is seen in the disproportionate attention and impact generated by finds that push "complex" or representational expressions further into the past (Aubert et al., 2019; Barham et al., 2023; Brumm et al., 2021; Hoffmann et al., 2018; Schmidt et al., 2019) and in the popular and scholarly discourses surrounding them (Hoffmann et al., 2020; Metcalfe, 2023; Mithen, 2014; Sample, 2018; Schmidt et al., 2019; White et al., 2020; Wynn et al., 2016, 2021). 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 (Foley, 2016; Maynard Smith & Szathmáry, 1997). Moreover, it appears probable that the human–chimpanzee last common ancestor, though plausibly importantly different from any individual living ape (Lovejoy, 2009; Püschel, Bertrand, O'Reilly, Bobe, & Püschel, 2021; Sayers, Raghanti, & Lovejoy, 2012 but see Whiten et al., 2010), had more in common with other extant apes than with *H. sapiens* (Kinzey, 1987; McGrew, 2010; Püschel et al., 2021; Stanford & Allen, 1991). However, even assuming a plesiomorphic (i.e., ancestral) common ancestor between 5 (Kumar, Filipski, Swarna, Walker, & Hedges, 2005) and 12 (Püschel et al., 2021) Ma, the trajectory and pace of human cognitive evolution remains unresolved. Although 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 (Barham et al., 2023; Breyl, 2021; Harmand et al., 2015; Hoffmann et al., 2018; McBrearty & Brooks, 2000; Scerri & Will, 2023; Shea, 2011b), 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 mentioned 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; Coolidge et al., 2012; Hahn, 1986; though see Fig. 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, pp. 120–121), a narrative that has had weighty material consequences (Elkins, 2022; Layton, 2001; Ndagala, 1985). Although 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 that, 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.

Although certain researchers have made this precise point (e.g., Haidle, 2016; Sterelny, 2021b), such discussions have often focussed on the Australian continent (Balme, Davidson, McDonald, Stern, & Veth, 2009; Hiscock, 2007), and particularly the indigenous people of Tasmania (Haidle, 2016; Oswalt, 1976) whose material culture is sometimes framed as an aberrant case of cultural loss (Henrich, 2004). Moreover, discussions have been, by-and-large, nonquantitative (Haidle, 2016) and often appear as asides or footnotes (Hiscock, 2007; Kelly et al., 2023; Sterelny, 2021b). There is a 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 artefactual repertoires, and (2) whether there are processes, unrelated to cognition, that affect the likelihood of symbolic and other artefacts leaving an enduring signature.

Although 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 (Murray et al., 2020; Sykes, 2015; Wadley et al., 2020), evidence of prehistoric symbolism is frequently the most prominent (Leder et al., 2021; Sehasseh et al., 2021; Wilkins et al., 2021), and is often at the forefront of both academic discourse (Baquedano et al., 2023; Hoffmann et al., 2018; Kelly et al., 2023; Klein, 2017; McBrearty, 2013; Mithen, 2014; Pomeroy et al., 2020; Tattersall, 2017a; Wadley, 2021; White et al., 2020) and popular accounts (Harari, 2014; Harari et al., 2020). For ease of coding, analysis, and discussion, therefore, the present investigation focusses primarily on "symbolic evidence," broadly defined (sect. 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, p. 179) or differences in capacity or potential (Klein, 2017, 2019; Mellars, 2010; Mithen, 2013; Wynn et al., 2016), some invoke mixed models involving both cultural and somatic change (Conard, 2010; Kelly et al., 2023; Knight, 2010; Wadley, 2013, 2021), and some prefer purely cultural evolutionary models that 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.

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Figure 1. Top: Illustration of Mbuti bark cloth (pongo), reprinted from Tanno (1981). Bottom: Photograph of a Hadza unfired clay doll (olanakwiko), 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.

The findings presented here demonstrate, empirically, that complex cognition *does not* necessitate extensive symbolic material culture, and that certain schemata for identifying behavioural modernity (intrinsic or otherwise) would risk excluding contemporary humans. Moreover, results highlight the primacy of extragenetic factors, including ecology, demography, artefact function, and residential mobility, and the limitations each place on artefact repertoire size and material selection (see Collard et al., 2011; Collard, Kemery, & Banks, 2005; Henrich, 2004; Shott, 1986; Sterelny, 2021a; Torrence, 1983). 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 & 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 (Marlowe, 2010; Skaanes, 2015; Smith, 1977; Woodburn, 1970). The author's field research is with the Hadza (Stibbard-Hawkes, Attenborough, & Marlowe, 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 (Ichikawa, 1998; Skaanes, 2015; Solomon, 1997; Stagnaro,

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Stibbard-Hawkes, & Apicella, 2022), myths, oral histories (Kohl-Larsen, 1956; Osaki, 2001), rituals (Bundo, 2001; Skaanes, 2015; Turnbull, 2015), and musical traditions (Bundo, 2001; Marlowe, 2010; Nurse, 1972). All have fully recursive languages that are phonologically and syntactically complex (e.g., Sands & Güldemann, 2009; Vossen, 2013).

These populations were chosen for four 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, 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 of the continent 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 & 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 (see, e.g., McBrearty & Brooks, 2000; McBrearty & Stringer, 2007; Mellars, 2005), 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 obtained from trade, whereas 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, Cross, Herlosky, Ford, & Crittenden, 2021; Stibbard-Hawkes & Apicella, 2022). Many Mbuti continue to hunt with nets, although regularly supplement their diets with food obtained from neighbouring farmers, of whom there are an increasing number (Terashima & 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 (Blurton Jones, 2016; Marlowe, 2010). 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 and 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 & Ichikawa, 2003). In certain tools, traded materials such as iron and plastics have replaced traditional media such as wood and stone. There are also some instances of minor technological exchange between these populations and their neighbours (Nurse, 1972; Tanno, 1981). 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 that affect the preservation and recovery of organic, or artefactual (Behrensmeyer, Denys, & Brugal, 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 byproducts (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 (see, e.g., O'Connor, Solazzo, & Collins, 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.

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Codings were based on material only and do not account for depositional environment. Except in rare conditions (e.g., anaerobic marsh, permafrost, desert), postdepositional 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., Barham et al., 2023; d'Errico et al., 2012; Thieme, 1997; Wadley et al., 2020). However, such conditions are rare and, though taphonomic processes do not cause information loss at a consistent rate (Surovell, Byrd Finley, Smith, Brantingham, & Kelly, 2009), preservation probability decreases at greater time depths (Langley, Clarkson, & Ulm, 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, 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 "Data availability" section.

8. Symbolism and artefact function

I also created a binary variable with the purpose of capturing whether a specific artefact would, by certain schemata (e.g., Klein, 2017; Mithen, 2014), constitute evidence for complex cognition. This was not straightforward as even those scholars who seek to employ artefactual data in the study of past cognition recognise that inferring cognitive capacities from artefacts is "notoriously tricky" (d'Errico & Henshilwood, 2011, p. 56) and often "more art than science" (Coolidge, Overmann, & Wynn, 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 (Ames et al., 2013; Davidson, 2010). Others restrict definitions to symbolic evidence, broadly construed, including ochre use, and decorative modifications such as polishing (e.g., d'Errico & 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 (Harari et al., 2020; Kurzgesagt, 2016) and still garners extensive research attention (Kelly et al., 2023; Leder et al., 2021; Vyshedskiy, 2019) 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 nonutilitarian function or modification. This included all musical instruments, toys, dyes, and pigments, practical items with nonfunctional decorations (e.g., scored arrows, decorated bows), dolls, beads, jewellery (e.g., necklaces, rings), alongside as items of clothing that 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, and so on.

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 (Barham & Everett, 2021; González-Ruibal, Hernando, & Politis, 2011; Wiessner, 1983). 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 (Mithen, 2014; Sterelny, 2011). And although artefacts have been linked by some to grammatical and linguistic ability (Klein, 2017; Stout et al., 2021; Tattersall, 2017b), others have highlighted the attendant inferential risks and pitfalls of trying to infer syntax or language skills from material representations (Botha, 2008, 2010; Henshilwood & Dubreuil, 2011; Sterelny, 2014). Often, sophisticated artefacts need not necessitate sophisticated cognition *at all* (Sterelny, 2014) and may be explicable through simple decision rules (Walsh, Hansell, Borello, & Healy, 2013) and/or sensory stimulation/exploitation (*sensu* Verpooten & 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 (Lew-Levy, Andersen, Lavi, & Riede, 2022; Riede, Lew-Levy, Johannsen, Lavi, & Andersen, 2023), 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, personal communication, 2020). 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)

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items of furniture or shelter; (7) foraging tools (e.g., arrows, digging sticks); (8) cooking, eating, and food-preparation tools; and (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 and (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, although the model outputs reported in Tables 2 and 3 are sufficient to provide broad inferences about population-level patterns, they cannot replicate the fidelity of, for example, a site-level analysis of refuse production (see O'Connell, Hawkes, & Jones, 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 who want more technical detail, a comprehensive reporting of results, including full-model estimates, model definitions, and model selection outputs, see the "Data availability" section, where commented analysis scripts and tabulated study data can also be found.

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 aim of the study was 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; Fig. 1) and numerous plant-based pigments, dyes, and body paints (Tanno, 1981). There exists much ancient Kalahari rock art but, although there are records of other Kalahari foragers producing it (Solomon, 1997), the G//ana traditionally do not (Tanaka, 1979, p. 197). Although there are accounts of ochre (or possibly *Pterocarpus* dye) use among the !Kung as bridal face paint (Marshall, 1976, pp. 276–277), and the /Xam as a leather-tanning agent (Wadley, 2005), a literature search yielded no records of dye use among the Hadza or G//ana. Moreover, despite the availability of bone/ivory, none of these populations produce carved bone figurines.

Burial, especially with grave goods, often features in discussions of prehistoric cognition (see, e.g., Pomeroy et al., 2020; Sommer, 1999; Sterelny, 2014; Wadley, 2021). Although, as elsewhere, death has important cosmological significance, there is little elaborate or symbolic burial. Although 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). Although 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).

Table 2. Mean fitted probabilities with 90% credible intervals (CIs) for plant-derived, animal-derived, and inorganic materials with population and trade as predictors

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

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Table 3. Mean posterior probabilities with 90% CIs for artefacts 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, and model 3 includes trade and symbolism

Model no.	Traded	Function	Mean *p*, Mbuti	90% CI	Mean *p*, Hadza	90% CI	Mean *p*, G//ana	90% CI
3.1								
	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
3.2								
	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
3.3								
	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

Neither use extensive grave goods (Woodburn, 1982), though people may be buried with water gourds or digging sticks (Skaanes, 2015; Woodburn, 1982). Possessions are alternatively shared out or discarded (Skaanes, 2015; Turnbull, 1976). 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, although 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.

Although 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 (Fig. 1) and cloth dolls of wrapped, unmodified rock or wood, whereas the Mbuti, alongside habitual pigment use, also produce elaborate bark honey containers. Each population produces musical instruments of several types (Marlowe, 2010; Tanno, 1981), with and without traded materials. Moreover, 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. Although it is conceivable that a human population might not create any material symbolic expressions, the present data do not make this case. However, when

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considering those artefacts that 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 one-third (mean $p = 0.32$, 90% highest density credible intervals [HDCI] = 0.27–0.37). This was predominantly a 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 nonbiodegradable; and were often acquired for this reason.

This is important. Although nontraded 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 more recent. To better leverage the current datasets as a model for 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 that might constitute evidence of symbolism (Table 3). 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 a consequence of a single material – ostrich eggshell – and to better understand these results, it is useful to consider each artefact individually.

Table 4 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 4.1), 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, whereas four incorporated ostrich eggshell, a material not in contemporary use by the Hadza. Ostrich-shell beads appear early in the African archaeological record (d'Errico et al., 2012; McBrearty & Brooks, 2000) 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) that 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 such as eggshell, bone (Table 4.1), or marine shell (e.g., Miller, Sawchuk, Reedman, & Willoughby, 2018); the Hadza traditionally produced beads from organic media including twigs, tubers, and acacia pods (Woodburn, 1970) whereas 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, p. 85) and G//ana (Hitchcock, 2012) or weaving plant fibre as among the Mbuti (Tanno, 1981). Thread making is another complex multistep process that can be culturally transmitted, and lost. Despite its deep history (d'Errico et al., 2012), such knowledge is neither obvious and 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 d'Errico et al., 2012; Marlowe, Apicella, & Reed, 2005) alongside technological exchange with neighbouring populations (Nurse, 1972; Tanno, 1981). Despite this, under normal conditions of preservation, certain criteria to identify cognitive modernity in the archaeological record (Klein, 2017; Mithen, 2013) 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). The 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 4.2) because most materials attained from trade were not available in the deep past yet are overwhelmingly inorganic, hard wearing, and long-lasting (Fig. 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. Although there is good reason for excluding them, their exclusion may mask symbolic artefacts that would otherwise include widely available yet enduring media such as stone and bone. For example, many artefacts that previously incorporated flaked or worked stone (e.g., knives;

Table 4. 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

Table no.	Artefact	Population	Material 1	Material 2	Material 3	Material 4	Material 5
4.1 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)			
	Ritual horn	Mbuti	Ivory or bongo horn				
4.2 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				

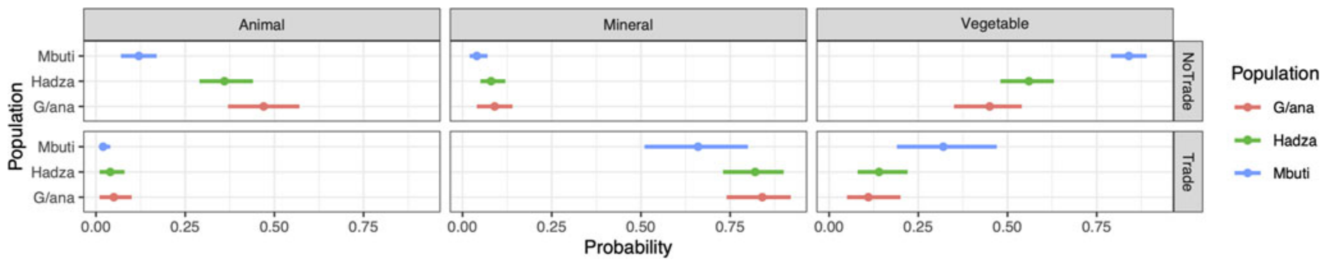

Figure 2. Bar plots showing fitted mean probabilities and 90% CIs for each of the three study populations of using animal-derived, inorganic, and plant-derived tool components. Untraded components above, traded components below.

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 4.2 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 & 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 a review) and, once again, constitute a complex technological innovation that is not universal.

The majority of other artefacts in Table 4.2, especially from the Hadza, contain glass beads. Although beads are often manufactured from enduring materials such as 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 nontraded materials. Bracelets are alternatively manufactured from leather or fur by two study populations though, again, not from any long-lasting materials.

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 4.2 are either instruments or incorporate metal bells. Bells are manufactured by the Mbuti from wood though no records of nontraded 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 nontraded materials, although there are reports of Hadza hunting bows, manufactured from wood and sinew, being played as instruments (Woodburn, 1970).

Thus, although traded materials, including metals, have replaced traditional media such as 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. Moreover, those alternatives which are not ephemeral are often ecologically bounded (ostrich eggshell; marine shell) and/or difficult to work with.

11. Is there population-level variability independent of differences in cognitive capacity?

Several authors (Haidle, 2016; Hopkinson, 2011; Scerri & Will, 2023; Shea, 2011b) have argued that interpopulation behavioural variability and ecological flexibility, rather than cognitive change, are sufficient to explain many differences in past material culture. Many highlight that population-level differences in artefactual records are rational responses to varying subsistence environments (see Collard et al., 2011; O'Connell, 1995; Shea, 2011a). Thus, the second aim of the study 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. Although 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 (Fig. 2). Although some variation results from culturally acquired knowledge, much is probably a 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., Blinkhorn, Timbrell, Grove, & Scerri, 2022; Brumm, 2010; Scerri, Roberts, Yoshi Maezumi, & Malhi, 2022). The present findings highlight the primacy of ecology in shaping the material record.

The Hadza and G//ana both traditionally occupy savannah bushland (Blurton Jones, 2016; Tanaka, 1979) and it is unsurprising that both were more similar to each other in material use than to the 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 (Fig. 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 & Watts, 2017), network structures (Sterelny, 2021a), cultural exchange

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(*sensu* Granito, Tehrani, Kendal, & Scott-Phillips, 2019), and cumulative innovation (Dean, Vale, Laland, Flynn, & Kendal, 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, for example, those exploiting perennially available aquatic resources (Jeffery & Lahr, 2020; Singh & 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 this hypothesis directly. Other authors have investigated ecological determinants of forager toolkit complexity and repertoire size (Collard et al., 2005, 2011; Shott, 1986; Torrence, 1983) 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 & 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. Although estimates were wide, these trends were statistically real and models including tool function substantially outperformed those without in a LOO model selection (see the "Data availability" section).

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 among 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 3). 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 the 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 a 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. The 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 (Brumm et al., 2021; Coolidge et al., 2012; d'Errico et al., 2012; Klein, 2017; Wadley, 2016; Watts et al., 2016) – 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 & 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 semisedentary populations, who store seasonally abundant resources such as acorns, or anadromous fish (Kelly, 2013; Testart et al., 1982). 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; Kline & Boyd, 2010; Powell et al., 2009). 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 & Boyd, 2010). This idea has been debated (d'Errico & 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., Dean et al., 2014; Tennie, Call, & Tomasello, 2009) 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 & 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 & 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 (Sterelny, 2016; Tattersall, 2017b), though not all (Klein, 2017) late/recent language origin models view language as a cultural innovation, which enables new modes of thought and artistic expression. Some view "behavioural modernity" as grounded in extragenetic 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; Sutton, 2020; Tribble & Keene, 2011). Here, the mind is seen as "extended" (Clark, 2001; Sterelny, 2017, 2019; Sutton, 2020; Wynn, Overmann, & Malafouris, 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 that make no strong claims about innate capacities (Sterelny, 2011, 2016, 2019). These models sidestep a host of inferential difficulties (Shea, 2011b; Speth, 2004), chronological complications (Scerri & Will, 2023; Sterelny, 2014), 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 (Bolhuis et al., 2014; Sterelny, 2011, 2016, 2014, 2017; Tattersall, 2017a; Tennie, Premo, Braun, & McPherron, 2017) 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 such as innovation and transmission (Tennie et al., 2017) but make second-order claims about the intrinsic capacities of extinct humans (see Sterelny, 2020; Sterelny & 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 *H. heidelbergensis* 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). Although 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 is not interpretive but terminological. I see two primary issues. First, although terms such as "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 (Bar-Yosef, 2002; Klein, 2002; Mellars, 2005, 2006), especially as the term "modern" retains its original meaning elsewhere (Klein, 2019). Additionally, although it is useful to consider technological and demographic tipping points (Sterelny, 2019; Sterelny & Hiscock, 2024) the term "behavioural modernity" also inherits many attendant definitional difficulties as a threshold, trait-list, or concept (Ames et al., 2013; Henshilwood & Marean, 2003; Meneganzin & Currie, 2022; Scerri & Will, 2023; Shea, 2011b; Stringer, 2002). Even the word "cognition," although 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 equal 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 & O'Connor, 2008; Davidson & Noble, 1992; Habgood & 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 might have queried the notion they were less modern than their forebears because they lacked boats.

Even discussion of cognitive ecologies (Sutton, 2020; Tribble & Keene, 2011), niches (Tribble & Keene, 2011), or of past peoples living "such different lives" (Sterelny, 2019), may lead us to overemphasise cultural distinctions. Although technology is indisputably 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 orthogenetic reasoning. Henrich (2004) is clear that indigenous Tasmania experienced no devolution across cultural domains (p. 203)

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accompanying technology loss. Moreover, terminologically choppy waters of this kind are not unique to cognitive archaeology (see, e.g., Lavi, Rudge, & Warren, 2024). Yet in, for example, 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., Haidle, 2016; Henrich, 2004; McGrew, 1987; Oswalt, 1976; 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.

15. Limitations

Although 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 & Daly, 1999). These data are sufficient to demonstrate that contemporary humans do not inevitably produce enduring symbolic artefacts. However, to statistically investigate broader patterns (see, e.g., Collard et al., 2005, 2011; Shott, 1986; Torrence, 1983), a larger dataset is needed.

Second, these datasets represent a twentieth-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 because of some intrinsic (Klein, 2019) or context-bound (Henshilwood & Dubreuil, 2011) proclivity, or because it exists within a particular species' zone of latent solutions (see discussion by Sterelny, 2020; Sterelny & Hiscock, 2024; Tennie et al., 2016, 2017). Under this assumption, even were evidence for symbolism often absent, general cross-site temporal trends may still track species-level cognitive change.

This assumption, although 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, Clarkson, & Ulm, 2019) despite at least 50,000–55,000 years of continuous modern human occupation (Brumm & Moore, 2005; Habgood & Franklin, 2008; O'Connell et al., 2018), probably "mainly reflects the failure of early cultural expressions to be preserved and discovered" (Hiscock, 2007, p. 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 artwork (David et al., 2013; Langley et al., 2011, 2019). Yet, extragenetic processes of cultural evolution – invention, horizontal/vertical transmission, and cumulative change (e.g., Dean et al., 2014; Tennie et al., 2009) – 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.

16. Conclusion: 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 (Pascual-Garrido & Almeida-Warren, 2021; Shea, 2011b) 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 (Aubert et al., 2019; Wynn et al., 2009), elaborate burial (Sterelny, 2016), pigment, and dye production (Watts, 2010; Watts et al., 2016) – are either wholly absent or, when they do appear, effectively traceless. When traded materials (e.g., plastic; metals; glass) are excluded, certain schemata 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 two 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 use this material will leave greater evidence of symbolic behaviour than those which don't. This is significant as, despite the research attention paid to beadwork in discussions of cognitive evolution (Bar-Yosef, 2002; Kelly et al., 2023; Klein, 2017), for instance as "especially compelling evidence for 'symbolism'" (Klein, 2019, p. 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.

Third and finally, results show significant population-level differences in material use that create differences in artefact preservation probability. These do not stem from differences in cognition. Instead, they are a consequence of ecological differences in material availability and probably other population-level processes also, including demography and cultural transmission dynamics (see Scerri & 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 & Pinhasi, 2011), but

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also in population movement (e.g., Holden, 2002), health, and demography (Stock & Pinhasi, 2011; Wells & 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., Allsen, 2002; Greene, 1990). Innovations in manufacture and finance (Smith, 1778) in the eighteenth century substantially changed patterns of trade, production, and subsistence on a global scale, as did twentieth-century revolutions in information technology and communication (Leiner et al., 2009). Although these periods of revolution sometimes altered selective environments (Richerson, Boyd, & Henrich, 2010; Stock & Pinhasi, 2011), 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 (Conard, 2009; Hahn, 1986; Klein, 2017; Wynn et al., 2009), rather than evidencing the appearance of modern cognition (*sensu* Bar-Yosef, 2002; Klein, 2008; Sterelny, 2011), 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 *H. sapiens* populations similarly.

This is important not only in interpreting the material record, but also from a metascientific perspective. Notions of technological and societal advancement have been erroneously used as justification for discrimination against forager populations (Hennessey, 2020; Woodburn, 1997). Many researchers have highlighted that by equating material culture with advancement, we replicate many of the assumptions of progressive unilinear/social evolutionism (Milks, 2020; Shea, 2011b) grounded in late nineteenth-century thought (for reviews, see Mukherjee, 2016, Pt. 1; Olusoga, 2016, chs. 10–12). 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. Although 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 (Hoffmann et al., 2020; Mellars, 2010). Researchers attributing cognitive sophistication to other human species (d'Errico, 2003; Zilhão et al., 2010) or proposing gradual/mosaic chronologies (McBrearty, 2013; McBrearty & Brooks, 2000; Scerri & Will, 2023; Shea, 2011b), have often faced considerable pushback (Mellars, 2010; Mithen, 2014; Porr, 2011; Schmidt et al., 2019; White et al., 2020).

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 (Barham et al., 2023; d'Errico, 2003; d'Errico et al., 2003; Langley et al., 2008; McBrearty & Brooks, 2000; Sykes, 2015; Zilhão et al., 2010). 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 (Bagshawe, 1925; Elkins, 2022; Jacques, 1997; Kipling, 1899; Mukherjee, 2016; Olusoga, 2016), and its capacity to create false intuitions (Milks, 2020; Shea, 2011b; Speth, 2004), 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 *H. sapiens* populations (d'Errico & Stringer, 2011; Hopkinson, 2011; Milks, 2020; Shea, 2011b; Speth, 2004), and indeed members of our genus, as resulting from extragenetic processes. Similarly, we should be hesitant in inferring from the material record the absence of other important but traceless cognitive technologies (Coolidge et al., 2016; Sterelny, 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 & Balzeau, 2018; Mounier et al., 2020). However, the present findings highlight the risks of discounting perishable media (see Mithen, 2013; Pascual-Garrido & 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 (Klein, 2019; Sterelny, 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 that would reliably exclude modern humans.

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

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Open Peer Commentary

The Mbuti people still reproduce a 75,000 years old recursive pattern

Lluís Barceló-Coblijn*

Laboratori d'Investigació en Complexitat i de Lingüística Experimental-University of the Balearic Islands, Palma, Spain
lluis.barcelo@uib.cat
https://www.uib.eu/personal/ABjE5MTc3MQ/

*Corresponding author.

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Abstract

Modern humans don't always leave cultural or technological evidence. Yet, Mbuti artifacts, like net-hunting tools and patterns, reveal their modern cognitive capacity. They create geometric and musical structures requiring specific working memory seen in modern *Homo sapiens*. Evidence from Blombos Cave suggests these skills existed 75,000 years ago, underscoring shared cognitive abilities among all modern human populations.

The debate in the modern scientific community about the evolution of language has more than a century of history (Jastrow, 1886). However, initially, due to the absence of evidence, highly speculative or unfounded hypotheses were often proposed. This led the Société de Linguistique de Paris to prohibit the study of language evolution in 1866. As Stibbard-Hawkes recalls in his article, the continued absence of evidence was assumed to be evidence of absence of proof regarding the evolution of language. Moreover, the author convincingly argues that modern humans do not always leave evidence of what could be considered modern culture or even advanced technology. Analysis of data from the three cultures (Mbuti, G//ana, and Hadza) seems to suggest this.

Nevertheless, these three *Homo sapiens* cultures cannot entirely conceal characteristics of their modern cognitive capacity, which are evident in the cultural materials they produce. For example, the Mbuti pattern reproduced in Figure 1 of the present target paper comes from Tanno (1981), who described the Mbuti cultural materials made by means of plant strings and occasionally duiker skin. Among the many objects and plants described, Tanno detailed the nets for net-hunting, made of *Manniophton fulvum* strings through a complex process. This process involves making the bast into fibers, then twisting them into two threads, which the Mbuti twist again into a string on their thighs. (Tanno, 1981, pp. 19, 30). The Mbuti make their quivers from duiker skin, wooden bells for the dogs, baskets from *Eremospatha haullevilleana* strings, and mats from *Afaendidia conferta* leaves "by doubling them along the midrib and pricking them into each other in succession" (Tanno, 1981, p. 30; see also Fig. 14 on p. 31). Tanno also describes Mbuti clothes, like the "pongo" or barkcloth, also mentioned in Stibbard-Hawkes's target article. These objects feature very special drawing patterns characterized by recursive strings of geometrical, rhomboid figures; however, the original figure includes another drawing that shows a pattern of embedded geometrical objects. Extremely interesting is the "luma," a set of 12–15 pipes (made from the plant *Olyra latifolia*) of different lengths that produce various pitches, each played by one man in a coordinated manner, performing melodies and harmonies together.

The ability to manipulate geometric elements and/or create musical structures (which usually contain subordinate structures and elements, such as section, period, phrase, semi-phrase, and motif) requires a cognitive capacity that includes a specific working memory, that of modern *H. sapiens* (Manrique, Read, & Walker, 2024). The same can be said of syntactic structures, which can easily embed additional elements and even complex structures.

The syntactic capacity has been addressed from various areas of scientific research, but often encounters the difficulty of providing evidence of a cognitive capacity for which we have no evidence outside of the human mind. If the evidence is scarce but enough, it has sometimes been simply concluded that the presence of modern language is "inevitable" (Dediu & Levinson, 2018), or conversely, the stricter viewpoint is criticized for the lack of (more empirical) evidence because it seems that there is never enough evidence.

One must not be dogmatic, as nowadays we have new data from many different sources. Since the publication of the first data on Neanderthal DNA, many theories and viewpoints have had to be reworked. Accepting theories based on pigment residues or marks on the wall (Rodríguez-Vidal et al., 2014), which can hardly be justified as evidence of the recursion that is evident in nets, baskets, or the diamond pattern from the Blombos Cave, or extremely small remnants of fibers from a possible fabric (Hardy et al., 2020), may lead us to ignore data about endocranial ontogeny (Gunz et al., 2012), or even to dismiss it as irrelevant.

It appears that Neanderthal-Sapiens hybrids (or Denisovan-Sapiens hybrids) were not seen as problematic or detrimental to the archaic *H. sapiens* species. The evidence of introgressive hybridization is widely accepted and cannot be ignored, as it has very important implications for the concept of species (Scerri et al., 2018). However, this is also important regarding cognition and it does not seem to have been emphasized enough in the discussion on language evolution.

The Mbuti people reproduce, using limited means such as painting or fabric, a recursive pattern with rhomboid figures that essentially has no established limit. Precisely, we have clear evidence of this same recursive pattern, such as in remains from 75,000 years ago in the Blombos Cave (South Africa), found in more than one object, ruling out that this pattern emerged by chance (Henshilwood, d'Errico, & Watts, 2009).

If the ability to produce patterns like this is somehow related to the mental capacities of the brain, then it could be that they were already within the reach of *H. sapiens*, whose brain capacity appears to extend back to 160,000 years ago (Zollikofer et al., 2022).

All the plant-based products mentioned above are indeed perishable, unless exceptional conditions prevent it. However, there are elements that show a modern cognitive capacity behind them, with the power necessary to produce recursive patterns in drawings, musical pieces, and a multitude of structures made from braided fibers through complex manufacturing processes and the creation of knots and braids.

While it remains controversial and debatable whether other hominins could create the same types of objects as those mentioned above (nets, quivers, baskets, etc.), all present-day humans from all regions of the planet can produce this kind of patterns, and they can also learn any human language. Therefore, we should reflect the true relevance of the impact of genetic inheritance inherited from different species of the *Homo* genus on a common cognitive capacity in all current populations, which has existed for at least 75,000 years according to archaeological evidence.

The Mbuti people have established a connection through time between the patterns on their barkcloth and the patterns found in the Blombos Cave.

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Advancing paleoanthropology beyond default nulls

Matteo Bedetti[a] and Colin Allen[b]*

[a]Department of Pure and Applied Sciences, University of Urbino Carlo Bo, Urbino, Italy and [b]Department of Philosophy, University of California, Santa Barbara, CA, USA
m.bedetti1@campus.uniurb.it
colinallen@ucsb.edu
https://colinallen.dnsalias.org/

*Corresponding author.

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Abstract

While we are sympathetic with Stibbard-Hawkes' approach, we disagree with the proposal to switch to a "cognitively modern" null for all *Homo* species. We argue in favor of a more evidence-driven approach, inspired by recent debates in comparative cognition. Ultimately, parsing the contributions of different genetic and extra-genetic factors in human evolution is more promising than setting a priori nulls.

Stibbard-Hawkes' analysis of the taphonomic signature of the material culture of contemporary foragers is an innovative and useful contribution to the debate about "behavioral modernity" and the evolution of hominin cognition and culture. We are sympathetic with the author's basic contention that taphonomic and environmental factors mean that paleoarcheological absence of various kinds of artifacts should not be taken automatically as evidence for the "primitive null," that is, lower cognitive sophistication in groups for whom the record of symbolic material culture is smaller or nonexistent, but rather as reflecting extra-genetic factors, such as demographic patterns, choice of materials, and so forth. This provides another strong argument against "single factor" genetic approaches (such as the one endorsed by Klein, 2008).

While sympathetic to Stibbard-Hawkes' approach, we disagree with his conclusion that we should switch from a primitive null to a "derived" or "cognitively modern" null that assigns every species of the genus *Homo* modern cognitive capacities "until proven otherwise." We think it is too early to endorse such a position. While we agree that late members of our genus, such as *H. neanderthalensis*, probably had a level of cognitive sophistication similar to ours, we think this is not the case when we take earliest hominins into consideration.

First, what is the evidence in favor of the assertion that the earliest representatives of *Homo* were cognitively modern? Why place the boundary of *Homo-sapiens*-level cognition at that precise point rather than another? It is true that absence of evidence is not evidence of absence, but this doesn't mean that every case of absence of evidence is the result of taphonomic biases or other phenomena. Sometimes, there is no evidence of a certain behavior in the fossil and archeological records because that species was not capable of the behavior.

Even after considering taphonomic and other sampling biases, there seems to be a clear signal in the fossil and archeological record between the Plio-Pleistocene transition (between 3.5 and 1.5 mya), when *Homo* emerged, and the present. Our analysis of the record suggests steadily increasing cranial capacity correlating with expanding behavioral repertoire, including more tool diversity, expansion into new habitats, and so forth, rather than the late Pleistocene takeoff that Stibbard-Hawkes also challenges. This pattern continues markedly even after the Plio-Pleistocene transition. But in contrast to Stibbard-Hawkes, we think that an evolution from the "primitive" character of the earliest human species to modern humans seems undeniable, and to state otherwise is to deny a correlation between increased cranial capacity and expanded cognitive abilities in our lineage.

The view that cognitive capacity and brain size are not correlated seems to be gaining momentum in certain areas of paleoanthropology. For example, when describing their excavations of *Homo naledi* fossils, and given the purported evidence for funerary behavior by this small-brained hominin, Fuentes et al. (2023, p. 4) write, "increases in brain size/EQ may not be a necessary precursor for the appearance of meaning-making behavior in the hominins." Endorsing this kind of position remains problematic, however, as the evidence in favor of complex cultural behavior by small-brained hominins is sparse and weak (see the public reviews of the three papers published by the *H. naledi* team, Berger et al., 2023a, 2023b; Fuentes et al., 2023) and conflicts with the existing evidence that cranial capacity and cognitive ability are somehow related in human evolution, as mentioned above.

This dispute echoes the debate about setting the correct null hypothesis in comparative cognition. Morgan's canon (Morgan, 1894) has often been used to justify attributing "lower" cognitive abilities to animals. Similarly, Dennett (1983) placed hypotheses in animal cognition research on a continuum going from "romantic" to "killjoy" – romantic hypotheses ascribe high cognitive sophistication to non-human animals, while killjoys ascribe low cognitive sophistication – and he took "killjoy" to be the default null. Others have argued against this default (Andrews & Huss, 2014; Mikhalevich, 2015). These attitudes affect the kinds of experiments that are pursued in comparative cognition and the cognitive abilities attributed by scientists to the animals they study.

We expect the debate that will arise from this target article, and ongoing discussion about *Homo naledi* and other small-brained hominins, will continue to echo the ongoing debate in the philosophy of animal cognition. Some researchers will tend to minimize the abilities of other representatives of our genus (Klein's view on Neanderthals' cognitive capacities, e.g., 2000) while others will lean in the opposite direction. Stibbard-Hawkes leans toward the romantics, given his rejection of the "primitive null" regarding species belonging to the genus *Homo*. But the wholesale extension of the modern cognitive capabilities to "all members of at least our genus" is unwarranted in our opinion.

This short commentary is not the ideal place to investigate parallels and differences between these two debates. Nevertheless, there is a useful lesson to be extracted from the philosophy of comparative cognition – and this should not be surprising, since we and our ancestors are animals. If it is necessary to establish a null hypothesis about the cognitive abilities of our ancestors, the best strategy is to do so in ways that are specific to the evidence rather than generic across different

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species. Several in the field of animal cognition have come to the same conclusion (Fitzpatrick, 2008; Mikhalevich, 2015; Sober, 2005). Clearly the kind of evidence available in the case of extinct hominins is very different from that available to those who study animal cognition, and the biggest challenge for paleoanthropology is to determine what evidence needs to be mobilized and how. Addressing this challenge is preferable to setting the null hypothesis a priori.

In summary, we think that rather than debating about setting the right null hypothesis, the more fruitful task for the science of human cognitive evolution is to find ways to separate empirically the different contributions of genetic and extra-genetic factors. Stibbard-Hawkes' ethnographic investigations helpfully point us in the right direction, with only minor course corrections required.

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Cultural innovation is not only a product of cognition but also of cultural context

Yotam Ben-Oren[a]*, Erella Hovers[b], Oren Kolodny[a] and Nicole Creanza[c,d]*

[a]Department of Ecology, Evolution, and Behavior, Silberman Institute for Life Science, The Hebrew University of Jerusalem, Jerusalem, Israel; [b]Institute of Archaeology, The Hebrew University of Jerusalem, Jerusalem, Israel; [c]Department of Biological Sciences, Vanderbilt University, Nashville, TN, USA and [d]Evolutionary Studies Initiative, Vanderbilt University, Nashville, TN, USA

Yotam.ben-oren@mail.huji.ac.il; https://scholar.google.com/citations?user=PxhzC24AAAAJ&hl=en&oi=ao
Hovers@mail.huji.ac.il; https://archaeology.huji.ac.il/people/erella-hovers
Oren.kolodny@mail.huji.ac.il; https://sites.google.com/view/oren-kolodny-homepage
nicole.creanza@vanderbilt.edu; http://nicolecreanza.com

*Corresponding authors.

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Abstract

Innovations, such as symbolic artifacts, are a product of cognitive abilities but also of cultural context. Factors that may determine the emergence and retention of an innovation include the population's pre-existing cultural repertoire, exposure to relevant ways of thinking, and the invention's utility. Thus, we suggest that the production of symbolic artifacts is not guaranteed even in cognitively advanced societies.

In the target article, Stibbard-Hawkes re-evaluates the archeological record of human cultural artifacts through the lens of the cultural repertoires of modern hunter-gatherers. He cautions against using artifacts as a barometer of the cognitive capacities of our extinct hominin ancestors, primarily because of the differential durability of cultural items: Modern hunter-gatherers, for example, have robust cultural repertoires, but relatively few of their tools would be durable enough to be recovered many thousands of years in the future.

We agree with this assessment and aim to push the argument further. While the author suggests that some prehistoric populations may have produced symbolic artifacts that were not preserved, we propose that populations could have had the necessary cognitive abilities and still not produce any such artifacts, or even more broadly not show evidence for cumulative culture. We suggest that cultural innovations, such as symbolic artifacts, are enabled not only by the cognitive skills of the individual but also by the broader cultural context of a population and other populations it contacts.

We previously suggested, using cultural evolutionary models, that both punctuated increases in culture and extensive loss of tools may often be stochastic byproducts of processes of cultural evolution (Creanza, Kolodny, & Feldman, 2017a; Feldman & Creanza, 2018; Greenbaum, Friesem, Hovers, Feldman, & Kolodny, 2019b; Greenbaum et al., 2019a; Kolodny, Creanza, & Feldman, 2015, 2016): Cultural traits spread in a population, they facilitate associated innovations and novel combinations, and they occasionally are lost. These processes result in dynamically fluctuating cultural repertoires, even in cognitively indistinguishable populations and in constant environments. This property of cultural evolution continues to be underappreciated in human history. Such dynamics may further affect populations' cultural repertoires when coupled with demographic or environmental change (Ben-Oren, Jaffe, & Kolodny, 2023a; Ben-Oren, Kolodny, & Creanza, 2023b; Ben-Oren, Strassberg, Hovers, Kolodny, & Creanza, 2023c; Creanza, Kolodny, & Feldman, 2017b; Fogarty & Creanza, 2017; Henrich, 2004; Powell, Shennan, & Thomas, 2009; Strassberg & Creanza, 2021). The insight of the target article – that many tool lineages would be unlikely to leave an archaeological record – adds another factor that may increase observed between-population cultural differences that are unrelated to cognitive differences.

The possibility that complex cognition does not immediately lead to the rise of complexity in material culture, sometimes not for tens of thousands of years, is supported by the archeological record (Hovers & Belfer-Cohen, 2006, 2022; Mcbrearty & Brooks, 2000; Paige & Perreault, 2024; Scerri & Will, 2023): Many hallmarks of modernity, including various manifestations of symbolic thought, appear anecdotally thousands of years before they begin to occur regularly, suggesting that the cognitive capacity for symbolic artifacts greatly preceded their establishment in the record. This is true for ochre (Henshilwood, d'Errico, & Van Niekerk, 2011), jewelry (Vanhaeren, d'Errico, Stringer, & James, 2006; Zilhão et al., 2010), as well as the precocious appearance of architectural features in Africa at ~476 kya (Barham et al., 2023) or among European Neanderthals at ~176 kya (Jaubert et al., 2016) followed by a long hiatus until architecture appears again in the archaeological record of the Upper Paleolithic after 50 kya.

Such early instances of symbolism, along with other technologies that are considered advanced (e.g., architecture, figurative art), raise the question of why symbolic artifacts were not *widely* adopted earlier. Differential preservation may be a factor, as suggested by the target article. We suggest that deeper, systemic cultural processes may also play a role: This phenomenon may be explained by a negative ratcheting effect in which some traits are easier or more likely to be lost than to be acquired. One factor that may affect the probability of an invention to occur, as well as to be retained, is its usefulness. It is possible, thus, that symbolic artifacts had greater utility in some populations than others. It has been suggested, for example, that one early function of symbolism was communication and maintenance of social cohesion across large populations. If that is the case, symbolic artifacts might have been more likely to be established when populations became more interconnected (Bar-Yosef, 1997; Hovers, 1990; Hovers & Belfer-Cohen, 2022). Arguably, the establishment of symbolic artifacts could create a feedback loop, allowing for higher social cohesiveness, which in turn favored greater use of symbols.

Finally, we suggest that it may be the case that some culturally related cognitive capacities cannot develop in an individual without appropriate cultural scaffolding at early developmental stages. By way of analogy, just as the development of linguistic skills requires exposure to language in infancy (Lenneberg, 1967), it could be that symbolic thought requires early exposure to symbols. Chimpanzees, for example, show naturally no evidence of a capacity for language, yet are cognitively able to learn words in sign language once exposed to them and teach them to other individuals (Gardner & Gardner, 1969); similarly, the potential for symbolic thought could have existed in early humans but was unrealized in most populations for extended periods in prehistory. More generally, we suggest that beyond the dependency of many cultural traits on pre-existing traits and cultural context, there may be a far more fundamental challenge for the development and multi-generational retention of certain cultural complexes, such as language or the production of symbolic artifacts.

In conclusion, for any cultural trait to appear in the archeological record, it needs to be invented, adopted, and preserved. We suggest that each of these steps is governed by multiple factors other than the cognitive capacity of the individual, meaning that while symbolic artifacts may be proof of sophisticated cognitive abilities, their absence does not rule out the existence of such abilities.

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Behavioural modernity is dead: Long live behavioural modernity

Matthias A. Blessing[a,b]*

[a]Anthropology Department, University of Connecticut, Deep History Lab, Storrs, CT, USA and [b]Department of Geosciences, Eberhard Karls University Tübingen, Working Group Older Prehistory and Quaternary Ecology, Tübingen.
matthias.blessing@uni-tuebingen.de

*Corresponding author.

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Abstract

Using Neanderthal symbolism, I extend on Stibbard-Hawkes to show that reconsidering the link between cognitive capacity and material culture extends beyond matters of preservation. A reconceptualization of behavioural modernity inclusive of both extant and extinct populations must begin with an honest theoretical separation of biological and behavioural modernity, which requires to critically engage with how we frame the underlying questions.

Stibbard-Hawkes makes a timely contribution to an ongoing debate in hunter-gatherer archaeology. He correctly identifies symbolism as an emergent consensus among archaeologists to identify behavioural modernity in a cognitive sense and outlines the inferential difficulties of linking material culture to cognitive capabilities, to which he adds a quantitative account on the likelihood of preservation of symbolic artefacts from three different hunter-gatherer groups.

This contribution comes at a time when many archaeologists have seemingly settled for symbolism as the benchmark of behavioural modernity in a cognitive sense, but the problem extends beyond matters of preservation because of another dimension to which behavioural modernity is intricately linked: The question of when humans became "like us" (Conard, 2008, 2010; Wadley, 2013). Decades of debate (Ames, Riel-Salvatore, & Collins, 2013; Henshilwood & Marean, 2003; McBrearty & Brooks, 2000; Mellars, 1989; Nowell, 2010; Scerri & Will, 2023; Shea, 1998, 2011; Zilhão, 2007) have tried to refine the theoretical connection between a variety of technologies and behaviours and how these can function as indicators of behavioural modernity. In theory, these efforts reconceptualized behavioural modernity in a way that opened the possibility for hominins other than *Homo sapiens* to be recognized as behaviourally modern as well. However, the very question of what makes *us* different from other hominins is based on a presumed (genetic) purity concept (Keel, 2017) which almost automatically creates a dichotomous hierarchy between "archaic" and "modern" because we are the only hominin species remaining (Peeters & Zwart, 2020). This is exemplified in the way symbolic evidence in Neanderthals is discussed.

More often than not, evidence for symbolic behaviour in hominins other than *Homo sapiens*, especially in Neanderthals, is acknowledged but at the same time discounted as not rich enough to qualify them as "fully modern." This is partly due to a lack of theoretical engagement with semiotic theory (see also Wynn, Overmann, & Coolidge, 2016), but also due to double standards in interpretation where, for example, personal adornments count as symbolic evidence in *Homo sapiens*, but they do not for Neanderthals (Botha, 2008, 2010; Wynn et al., 2016). Operating in such a theoretical void also leads to overreaching interpretations of discoveries (e.g., Baquedano et al., 2023), making evidence for Neanderthal symbolic behaviour easy to dismiss. We are almost reminded of the well-known joke that archaeologists will interpret anything of which they do not know the function as "ritual." In Palaeolithic archaeology it seems that anything that has no subsistence-related function will qualify as symbolic. This practice does little to overcome the historic misconceptions about Neanderthals that were based on a "merciless" mischaracterization rooted in the race science of the nineteenth and early twentieth century (Madison, 2020, 2021). Putting aside the complex theoretical underpinnings of recognizing symbolism for the sake of argument, even one artefact of symbolic nature in the archaeological sense would prove Neanderthals' cognitive ability to produce them. The fact that they manufactured pendants (e.g., d'Errico et al., 2009; Zilhão et al., 2010) and buried their dead (e.g., Stiner, 2017), should lead us to this conclusion. We certainly rely on symbolism more than any other species we know of today and this seems not to be the simple result of preservation (Kelly, Mackie, & Kandel, 2023). However, as far as cognitive capacity is concerned, the frequency of symbolic artefacts should not matter as a single one would establish the capacity to produce them. Stibbard-Hawkes' analysis of living populations' symbolic lives and their low chances of being recognized as fully modern by archaeological standards powerfully shows that putting all our inferential eggs into one (symbolic) basket is not a viable way forward.

In fact, any generalized threshold for what counts as modern, or in other words, what it takes to be human, will exclude some populations on a variety of grounds highlighted by Stibbard-Hawkes. Since there is no one answer to the question of what it means to be human, the assumption that we will eventually find the one difference between us and not us (e.g., Meneganzin & Currie, 2022) will always lead to the constant arbitrary moving of the goal posts, which characterized much of the debate on behavioural modernity in the past (see, e.g., the discussion in Blessing, 2023).

The suggested solutions for this problem range from recognizing Neanderthals and *Homo sapiens* as archaeologically indistinguishable (Villa & Roebroeks, 2014; but see Wynn et al., 2016), to changing the terminology (e.g., Shea, 2011; Wadley, 2013) – as also suggested by Stibbard-Hawkes – or abandoning the concept altogether (Shea, 2011). Changing the terminology, be it cultural complexity or behavioural variability for instance, will suffer from similar inferential issues as behavioural modernity does (e.g., Conard, 2011; Nowell, 2011), though it might provide us with a less loaded term. Even though Stibbard-Hawkes throws into question the link between material culture and cognition, abandoning the question of what makes or made us human should not be the conclusion we reach here and is not what he calls for. Some recent publications from the field of genome-wide association studies, or the continued use of national IQs, which I will not honour with a citation here, show that race science is, sadly, alive and well and therefore what is at stake. Thus, retreating from this field of research would mean to leave the playing field – once more – to racist misconceptions about human evolution and to perpetuate the cycle of marginalization of non-western lifestyles.

What we need instead is a theoretical reconceptualization that honestly allows for other species to be recognized as behaviourally modern (or whichever term one might prefer). Conflating the question of what it means to be human and when humans became like us presupposes that only we can be human. A continuation of this conflation will always lead to theoretical shortcomings and unbridgeable inferential gaps because there is no one way to be human. It also shows that, despite all notions to the contrary, archaeology was never truly ready to divorce biological and behavioural modernity. It is here, where an honest reconceptualization of behavioural modernity must begin.

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What would be pre-modern human cognition?

Nicholas Blurton Jones*

Department of Anthropology, University of California Los Angeles, San Clemente, CA, USA
nickbj@ucla.edu

*Corresponding author.

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Abstract

Stibbard-Hawkes's detailed demonstration that in the case of hunter-gatherer artifacts, absence of evidence is not evidence of absence must never be forgotten. The belief that there is a single coherent "human cognitive capacity" difference between modern humans and some unspecified earlier form should be rigorously re-examined.

The first message of Stibbard-Hawkes's target article is loud and clear and very important: Many complex, personally made objects essential to hunting and gathering would leave no archaeological record. It would be a serious error to interpret the absence of archeological evidence for such objects as evidence that they were not in common use. Nor can it be taken as evidence for the absence of whatever mental capacities are required to make and use these objects.

The author could have added a fourth example, the Dobe ! Kung, based on the extensive publications by Richard Lee and John Yellen. It is surprising that he omitted their foundational work, and the provocation of the field by Washburn and DeVore. It is sad if the younger generation pays so little heed to the founders of a field in which they are rapidly themselves coming to the forefront.

Was there a single unified leap forward?

I am happy to endorse the author's view that even the people with the least elaborate technologies are clearly human. San and Hadza are close to the root of the evolutionary trees sometimes produced by geneticists, but like other field workers I found no difficulty in interacting with either. A caveat, like other field workers before me, though the different ethic concerning ownership and exchange was easily recognizable, it was sometimes stressful for both parties. Later visitors may have benefitted from already established "working relationships" between researchers and their subjects.

The "advanced cognitive capacities" topic descends from Klein's proposal (as cited by Stibbard-Hawkes) that the archaeological record suggested a sharp difference around 50 kya, which among other things offered a quick explanation for why *Homo sapiens* spread so rapidly out of Africa and around the rest of the world, rapidly replacing previous populations. The idea of a sharp change in "cognitive capacity" was quickly challenged by McBrearty and Brooks (2000) based on data from African archaeology, to my mind successfully. But that leaves the 50 kya expansion lacking an explanation. I suspect an answer may be found in technologies that enabled women to better exploit higher latitude plant foods. Think Acorns. Women had the "advanced cognitive abilities" long before this time.

What would we mean by "advanced modern capacities," and how would we know them when we see them? The author could not resist being dragged into this intellectual quagmire and has made a significant start at draining the swamp. If we think we know what we mean by "fully modern human cognition" we must have some concept of "not yet quite modern," or "pre-modern cognition." If we do not have such a concept, we need to get one and tell the world what it might be like. A common starting point would be comparisons between humans and other apes. There are many, carefully studied by a generation of researchers. But the "fully modern human cognition" literature seems to concern itself with a range of abilities already far out of reach of any surviving apes.

It is easy to see the temptation to believe that there is such a cluster of advanced modern capacities, and that it comprises an inter-dependent set of features, and that they might all have come into being close in time. But can we just assume this and leave it unexplored? Would we all make the same list of indicators of "advanced modern capacities"?

Stibbard-Hawkes does imply that dating the transition, if it was a transition, is unlikely to be easy. The taxonomy of earlier forms of *Homo* is inevitably based on anatomical features. There is little else to guide the taxonomy. Connections between "cognitive capacity" and anatomy are likely to be remote at best. The relatively small volume of the apparently crucial ventromedial prefrontal cortex (Sapolsky, 2023), which Sapolsky, and Lockwood et al. (2024) link to prosocial behavior, is unlikely to be reflected accurately in skull shapes.

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Material culture both reflects and causes human cognitive evolution

Laura Desirèe Di Paolo[a,b], Ben White[c], Avel Guénin–Carlut[a], Axel Constant[a] and Andy Clark[a,c,d]*

[a]Department of Engineering and Informatics, The University of Sussex, Brighton, UK; [b]Children & Technology Lab, School of Psychology, The University of Sussex, Brighton, UK; [c]Department of Philosophy, The University of Sussex, Sussex, UK and [d]Department of Philosophy, Macquarie University, Sydney, NSW, Australia

L.Di-Paolo@sussex.ac.uk
B.White@sussex.ac.uk
a.guenin-carlut@sussex.ac.uk
A.Constant@sussex.ac.uk
Andy.Clark@sussex.ac.uk

*Corresponding author.

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Abstract

Our commentary suggests that different materialities (fragile, enduring, and mixed) may influence cognitive evolution. Building on Stibbard-Hawkes, we propose that predictive brains minimise errors and seek information, actively structuring environments for epistemic benefits. This perspective complements Stibbard-Hawkes' view.

We endorse much of the picture presented by the author, particularly since it avoids inferential pitfalls such as over-interpreting the minds of other species, or populations, as "archaic" or "primitive" compared to our own cognitive style. In our commentary, we draw attention to a different possible role for specific materialities. The idea we wish to explore is that different materialities (fragile, enduring, and mixed) may behave differently as levers for ongoing cognitive change and evolution. Our proposal integrates that of Stibbard-Hawkes.

Following the author, we see the mind, *any* mind, as formed by a constant dialectic process in which embodied, active agents make the most of *whatever* resources (persisting or perishable) happen to be available. Such exploitative activities fall naturally out of a view that has guided much of our own recent work – the so-called "Active Inference" view prominent in recent neuro-computational work (Parr, Pezzulo, & Friston, 2022). According to active inference, predictive brains seek to minimise "prediction errors" (the differences between their predictions and current waves of sensory evidence). But predictive brains also bring about actions, designed both to achieve practical goals (rendering certain predicted future states actual) and – crucially for our suggestion – to improve their own states of information in ways that will aid current and future success (e.g., Clark, 2015; Mirza, Adams, Mathys, & Friston, 2016). This is because, in order to minimise prediction errors over longer timescales, predictive brains learn to forage for information, structuring their worlds in epistemically useful ways (Clark, 2023; Parr & Friston, 2017). Instead of being merely a bearer of genetically transmitted abilities and a passive recipient of information, such brains proactively *predict* and by action *structure* the world so as to curate useful streams of sensory information. The upshot is that action-exploiting predictive brains will repeatedly outsource work using whatever social or material resources might be locally available. Digital and analogue calendars can both help us remember an appointment, and tallies made on clay or an electronic calculator can both help us in calculations. Particularly in the context of nomadic, hunter-gatherer populations, such active inference agents might well exploit – for epistemic gain – perishable but easy-to-find resources.

This suggests a double perspective on the minds of our distant ancestors. On the one hand, weaving baskets and huts, and making clothes and weapons from bio-organic materials (branches, leaves, etc.) may indeed *require* similar cognitive complexity to making a tool from a stone. On the other hand, engaging and exploiting these different materials might drive and intergenerationally alter minds and worldviews in different ways. The question then becomes not just that of determining which cognitive capacities were *required* for producing various (perishable and enduring) technologies but also one of understanding how different material technologies might slowly shape human cognitive functions and understanding. For example, a stone artefact is, by definition, more durable than one made of leaves or branches. Agents could encounter old stone tools or the remains of settlements little affected by the passage of time, even if made by extinct populations or by themselves when, at some long ago time, they crossed the same territory. Such encounters might aid in developing ideas such as "permanence" and "family inheritance." For a worked example involving the possible cognitive role of persisting structures and items, see Sutton (2020). By contrast, highly decomposable artefacts and relatively impermanent settlements might struggle to usher in this kind of temporally deep understanding.

Different materials might also impact cognitive processing in other ways. Consider the upshot of an incoming error signal (such as a mistake in some artefact's production). A stone tool and a woven container made of leaves and branches could both be fixed by working upon the affordances brought about by mistake. But in an attempt to avoid more serious damage such as breaking the core of a stone tool, an agent might be more motivated to take precautions and plan further ahead when using those materials. The production of woven objects might favour different (but equally useful) skills such as learning to replace some branches with different ones, or fully disassembling the artefact – unmaking it – and then making it again, recycling the same materials, shifting attention from the object to the process. When an environment provides both perishable and enduring materials, predictive brains enjoy multiple ways to offload work, minimise prediction error, and structure future beliefs. The interaction with, and modification of different materials allows us to train and tune our own cognitive functions in different ways, and to build various forms of epistemically rich environments. This eventually transforms cognitive processes in ways that may yet reflect the various physicalities provided by different materials.

In our own work, we have been investigating these alternative landscapes using the toolkit of active inference. We have shown, for example, how experience with a specific materiality (a decorated pot) might itself alter how agents approach a brand-new problem domain (Constant *et al*., 2021). We have also explored how achieved understanding becomes gradually "uploaded" into human-structured worlds, by encoding information and directing attention, via culturally agreed practices such as stopping at red traffic lights (Constant, Clark, Kirchhoff, & Friston, 2022). Recently, we have modelled a "toy version" of the knapping process. In our model, changes in the shape of the tool act to encode useful information by cueing attention and engaging action in different ways, reflecting alterations to the flow of predictions and prediction errors during the activity.

We applaud Stibbard-Hawkes for drawing attention to the importance of more ephemeral materials and alternative technologies. By approaching material culture using the promising toolkit of "Active Inference" we may respect this insight while exploring new ways of putting computational flesh on the idea that material culture does not just *reflect* but also helps to *bring about* the variable suites of competencies that we call "minds."

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Don't ignore cognitive evolution during the three million years that preceded the archaeological record of material culture!

Dean Falk*

Department of Anthropology, Florida State University, Tallahassee, FL, USA
dfalk@fsu.edu
www.deanfalk.com

*Corresponding author.

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Abstract

The target article rightly questions whether the archaeological record is useful for identifying sea changes in hominin cognitive abilities. This commentary suggests an alternative approach of synthesizing findings from primatology, evolutionary developmental biology, and paleoanthropology to formulate hypotheses about cognitive evolution in hominins that lived during the three million years that preceded the record of material culture (the Botanic Age).

Because of the target article's focus on symbolic artifacts, its analysis excludes "clothing items with a practical purpose … [and] undecorated subsistence tools, storage containers, utensils etc" (target article, sect. 8, para. 3). Some, if not all, of the excluded items are "plant-derived materials (e.g., wood, bark, fruit shells, seeds, leaves) and processed plant derivatives (e.g., rope fibre) … [that have] a 'weak' taphonomic signature" (target article, sect. 7, para. 4). Much of the analysis uses information about present-day foragers to reveal problems associated with making inferences about cognitive evolution based on the archaeological record of material culture. The paper is convincing and even brilliant, but it raises the question of how, given its conclusions, one might reasonably speculate about the emergence and evolution of advanced cognition in early hominins.

My approach complements the target article by focusing, in part, on some of the non-symbolic materials that the article excludes. I begin with the origin of hominins (5–7 million years ago) and move forward in time (Fig. 1). There is no record of material culture during the first half of hominin evolution, but findings from comparative primatology, comparative psychology, evolutionary developmental biology (evo-devo), paleoanthropology, paleoneurology, and ethnology may be synthesized to consider cognitive evolution during the three million years that preceded the start of the Stone Age. I call this prolonged period the Botanic Age (Falk, 2025) (Fig. 1).

Among primates, only great apes weave branches into arboreal sleeping nests each evening. The ability to construct these basket-like containers entails an intuitive grasp of how the physical world works, that is, "a kind of purely concrete and practical 'sense' of elementary implements," as documented long ago for chimpanzees (Köhler, 1925, p. 77). Evolutionary anthropologists have speculated that "nest building is not only properly placed within the realm of tool use, but it [the nest] is also the original tool that led to the mental and physical ability to use the tools we see today" (Fruth & Hohmann, 1996, p. 226). But how?

It is generally accepted that early hominins spent increasing amounts of time on the ground as they adapted to habitual bipedalism. Fossils show that, over time, feet changed from grasping to weight-bearing organs with aligned big toes. Consequently, today's human babies cannot grasp and ride on their mothers like all monkey and ape babies do (Ross, 2001). Evo-devo studies of motor reflexes in human babies and apes suggest that a gradual loss of clinging ability in early hominin infants was associated with babies falling off their traveling mothers in increasing numbers that may have caused severe infant mortality (Lindsay, 2019). Under these circumstances, mothers likely applied their nest-weaving skills to inventing life-saving baby slings woven from plant matter – possibly the first textiles (Fig. 1).

Although textiles have a weak taphonomic signature, fiber expert Helen Anderson speculates that the geometric zigzags and crosshatched patterns entailed in the earliest basketry may have contributed to hominins' eventual understanding of numbers, patterns, and structures and that, as such, incised artifacts

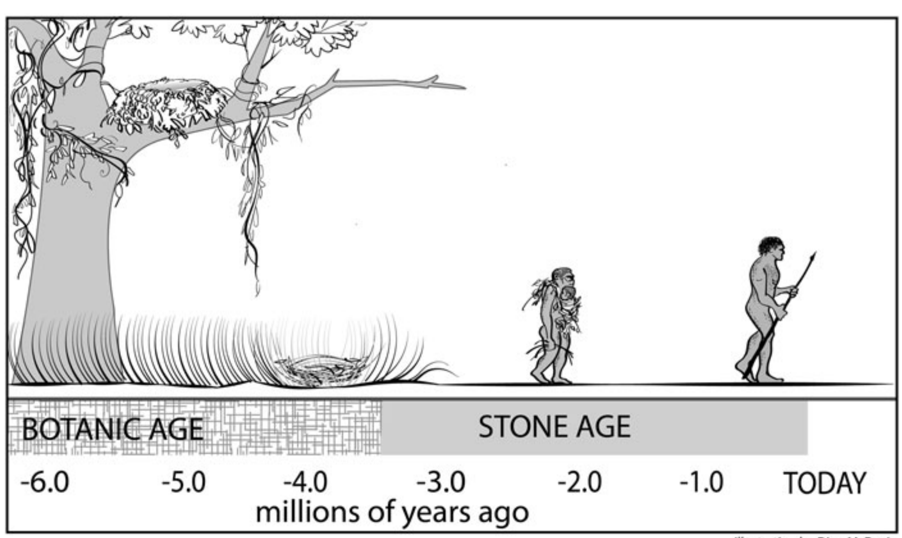

Figure 1 (Falk). Hominins existed for approximately three million years before the Stone Age began, a prolonged period identified here as the Botanic Age. As hominins became bipedal during the Botanic Age, babies lost the ability to cling to their mothers. In response, mothers likely used their skills for making tree nests to weave baby slings from vines and flexible branches. Highly perishable tools continued to be invented from botanical matter throughout the Stone Age, including wooden spears dated to around 400,000 years ago.

may be "used as proxies for an early capacity for symbolic thought" (Anderson, 2012, p. 183). Dated to about half a million years ago, hominins' earliest known geometric markings, etched on a shell in Indonesia (Joordens et al., 2015) and incised on slabs in South Africa (Beaumont & Vogel, 2006), postdate the Botanic Age. But evidence from the development of artistic skills in apes and children and comparative neuroanatomy of the primary visual cortices in primates including humans (Falk, 2024) is consistent with the hypothesis that the invention of woven botanical textiles with their inherent cross-hatched patterns could have occurred much earlier during the Botanic Age and been entwined (so to speak) with cognitive evolution.

Bipedalism was associated with more than the invention of material culture like baby slings. It may also have serendipitously resulted in new neurological connections that paved the way for the emergence of an ability to keep a beat (i.e., "entrain") to external rhythmic sounds as gestating infants simultaneously heard and felt the regular footfalls of their walking mothers (Larsson, Richter, & Ravignani, 2019). As detailed elsewhere (Falk, 2004) and recently updated (Falk, 2025), intermittent physical separation of infants and mothers caused by the loss of sustained grasping ability in the former may have prompted development of entrained reciprocal mother–infant vocalizations that contributed to the eventual emergence of motherese and, later, protolanguage. The ability to entrain to perceived external rhythms is essential for anticipating and keeping pace with clapping, dancing, foot tapping, music, and singing in addition to the linguistic utterances of conversational partners. This capability is unique in humans among primates and a necessary component of both music and language. The evolution of bipedalism likely seeded the emergence of the ability to entrain to rhythmic sounds *long before* this aptitude was exapted during the evolution of both music and language (Larsson & Falk, 2025).

The target article concerns the Stone Age because of its record of material culture. Although the appearance of some early stone tools, indeed, suggests that their makers had certain specifications in mind when knapping them, it is a bridge (or "cognitive leap") too far to accept them as proxies for major evolutionary advances in cognition. It is unreasonable to believe that hominins were cognitively stagnant during the three million years that preceded the appearance of the first stone tools. Despite the lack of a material record during the first half of hominin evolution, one can begin to speculate about the cognitive evolution of the earliest hominins by synthesizing evidence from multiple fields.

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Sports, team games, and physical skill competitions as an important source of symbolic material culture with low preservation probability

Andrew C. Gallup[a]* and Omar Tonsi Eldakar[b]

[a]David S. Olton Behavioral Biology Program, Department of Psychological and Brain Sciences, Johns Hopkins University, Baltimore, MD, USA and [b]Department of Biological Sciences, Nova Southeastern University, Fort Lauderdale, FL, USA
a.c.gallup@gmail.com
oeldakar@gmail.com

*Corresponding author.

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Abstract

Sports, team games, and physical skill competitions appear to be a human universal and may have been prevalent throughout the hominin lineage. These activities are cognitively complex and can be associated with a distinctive and symbolic material culture. Yet, many of the artifacts used by foraging groups for sports, team games, and athletic competitions often have a low preservation probability.

By analyzing three contemporary foraging groups, the target article highlights how the material culture produced by modern humans often lacks moderate–strong taphonomic signatures. As a result, the author argues that the absence of artifacts from enduring materials at hominin fossil sites should not be interpreted as a sign of limited cognitive sophistication among ancient humans. We support this general thesis while highlighting an important and overlooked source of symbolic material culture with low preservation probability: sports, team games, and other forms of physical skill competitions.

Within the evolutionary behavioral sciences, an often-underappreciated feature of human nature is our strong interest in physical competitions of sport, team games, and athletics (Gallup & Deaner, 2021). Ranging from childhood play to adulthood professions, these distinctive activities are impactful cultural and societal practices that appeal to humans on many levels and involve complex cognition and symbolic representation. Nearly all

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sports, team games, and athletic events have carefully designed rules and regulations that lead to the development of distinctive individual and/or team-based strategies and approaches for successful competition.

From an evolutionary perspective, the widespread nature of sports, team games, and physical skill competitions across cultures is considered a byproduct or manifestation of survival and reproductive adaptations (e.g., Deaner, Balish, & Lombardo, 2016; Furley, 2019). While the types of sports, team games, and athletic events can vary considerably across societies and geographic regions, many of the fundamental features of these physical competitions are common across diverse groups and activities, including chasing, hitting targets with projectiles, and stalking (Lombardo, 2012). Such behaviors, particularly when pursued by children and adolescents, could be adaptive in developing physical and social skills necessary for successful hunting and warfare (Lew-Levy, Reckin, Lavi, Cristóbal-Azkarate, & Ellis-Davies, 2017; Roberts, Arth, & Bush, 1959). Performance in such activities could also influence status or rank within groups (Lombardo, 2012). Consistent with this view, across most, if not all societies, men and boys are overrepresented and show greater interest and motivation to engage in sports (Deaner & Smith, 2013; Deaner et al., 2016).

Sports, team games, and physical skill competitions are obviously prominent cultural events and practices within post-industrial societies, but historically the evidence for participation in such activities among foraging groups was equivocal. In fact, it had traditionally been viewed that hunter-gatherers were perhaps the only human groups not to participate in competitive sports or games (Sutton-Smith & Roberts, 1971). In addition, observations of native Kenyans by Europeans in the early twentieth century depicted an outright absence of sport-like activities (Bale & Sang, 2013) beginning with Swedish ethnographer Karl Gerhard Lindblom (1916) stating that "no real sports" existed there (p. 425). However, more recent ethnographic data have refuted these claims, and it is now recognized that versions of sports, competitive team games, and athletics are quite common among hunter-gatherers and appear to be a human universal (Brown, 1991).

One example of a competitive team game that is prevalent among foraging cultures is coalitional play fighting. Defined as "play activity in which one coalition uses coordinated action and nonlethal physical force to attain, and prevent an opposing coalition from attaining, a predetermined physical objective (i.e., 'goal')" (p. 223), coalitional play fighting has been documented among diverse foraging societies across five continents (Sugiyama, Mendoza, White, & Sugiyama, 2018). Many of the activities classified as coalitional play fighting involve motor patterns of striking and throwing using balls and modified sticks (Sugiyama et al., 2018). Often taking the form of team contact sports or games, which "typically involve coordinated group action aimed at advancing an object (often a ball) into a predetermined zone, while contravening an opposing coalition's attempts to do the same" (Sugiyama, Mendoza, & Sugiyama, 2021, p. 94), coalitional play fighting is believed to function in rehearsing and calibrating motor and perceptual skills involved in intergroup aggression and lethal raiding. Observed in roughly half of the foraging culture clusters within Murdock's (1967) *Ethnographic Atlas*, these competitions clearly denote a form of complex cognition and symbolic representation yet involve material culture with low preservation probability.

In addition, one of the three foraging groups investigated in the target article, the Mbuti, engage in a physical skill competition ("tug-of-war") that pits men against women in which both sides sing back and forth as they pull on opposite ends of a vine rope (Turnbull, 1982). When an advantage emerges for one side, a member of the leading team switches and joins the opposition while playfully mimicking the mannerisms of their new team, for example, a man joining the women's side might sing in falsetto and a woman joining the men's side might chant in a deeper voice. These exchanges continue as each "tries to outdo the ridicule of the last, causing more and more laughter, until when the contestants are laughing so hard they cannot sing or pull any more, they let go of the vine rope and fall to the ground in near hysteria" (pp.142–143). While the Mtubi version of tug-of-war is ritualistic and intended to reduce intragroup conflict, this activity clearly stems from the original competitive form, showing the extent to which sports, team games, and athletics can further influence culture and society.

In summary, sports, team games, and physical skill competitions are a unique and omnipresent feature of human behavior that is cognitively complex, can be associated with distinctive material culture and symbolic representation, and may hold adaptive value in simulating hunting and combat and/or enhancing group dynamics. We posit that similar contests of physical skills were common in earlier *Homo* as well, perhaps originating following adaptations for overhand throwing and the emergence of hunting. Yet, within many contemporary foraging groups, and presumably in the past, many of the artifacts crafted and/or coopted for these activities would not leave an enduring signature. Therefore, the material culture associated with sports, team games, and physical skill competitions across a diverse range of foraging groups and habitats deserves further attention when considering evidence of cognitive sophistication.

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Proposing the DN(C)-model of material evidence for well-calibrated claims about past cultures

David J. Grüning[a,b]* and Lukas J. Grüning[c]

[a]Psychology Department, Heidelberg University, Heidelberg, Germany; [b]Department of Survey Design and Methodology, GESIS – Leibniz Institute for the Social Sciences, Mannheim, Germany and [c]Winckelmann Institute, Humboldt University of Berlin, Berlin, Germany
david.gruening@psychologie.uni-heidelberg.de
lukas.jan.gruening@student.hu-berlin.de

*Corresponding author.

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Abstract

Stibbard-Hawkes presents a much-needed case for distinguishing between different types of evidence for cognition in past cultures. However, he does not outline an applicable approach for moving forward in making claims about the cognition of past cultures. We present an initial model for calibrating both absolute and comparative claims about past cultures' cognition and other traits.

Stibbard-Hawkes presents a much-needed case for distinguishing between different types of evidence for cognition (e.g., its complexity and capacities) in past cultures, arguing in particular (and rightly) that evidence of sophisticated materials may be evidence for the absolute capacity of a culture, but the absence of such evidence does not allow inferences about the absolute incapacity of the culture, and that both cases do not per se allow claims about comparative capacity (between different cultures). While the author's critique is compelling, he does not present an overarching approach for moving forward in making claims about the cognition of past cultures. In the present commentary, we present an initial model for calibrating both absolute and comparative claims about cognition in past cultures by examining the diversity, necessity, and complexity (DNC) of the material evidence for a culture.

The DNC-model proposes three decision heuristics or preconditions for calibrating claims about the cognitive capacity of a past culture on the basis of its material evidence. Note that we define this type of evidence for a culture as the set of actual objects found that are definitely or very probably related to the culture of interest. These sets of objects have three characteristics by which they can be distinguished and which can subsequently be used to navigate well-calibrated claims about the absolute and comparative cognitive capacity of a culture.

First, as shown in Figure 1, the set of material evidence that exists for a past culture can be judged by its diversity. That is, the material evidence may differ at several levels, for example, from different overarching aspects of life in that culture (e.g., family, politics, or religion), with different intentions (e.g., for pleasure, persuasion, or war), and from different generations of that culture (e.g., Roman kingdom, republic, and empire). The diversity of an assemblage determines how comprehensive the researcher's perspective on the past culture is, with material evidence from different aspects of life increasing our understanding of the culture. Subsequently, the diversity of the material evidence available for a past culture centrally determines the extent to which claims about its cognition can be generalized (across individuals of that culture and across generations of that culture).

Second, the set of material evidence may include objects that are both necessary and unnecessary for a given culture. Specifically, highly culturally necessary material evidence is that which fulfills basic functions and needs in every, or at least the vast majority of, cultures, such as certain tools for obtaining and preparing food, or for creating shelter in the form of clothing and architecture. Comparatively culturally unnecessary evidence consists of objects that are more selective and not in themselves generally integral to a culture, such as religious objects (e.g., figurines depicting mythological or spiritually charged entities, such as the German Hohle Fels Venus, Conard, 2009; and the Hohlenstein-Stadel lion man, Hahn, 1986; Wynn, Coolidge, & Bright, 2009) or objects for certain pleasurable activities (e.g., bone flutes for producing certain melodies; Conard, Malina, & Münzel, 2009). The overall level of necessity represented in the material evidence set of a past culture determines the extent to which researchers can make comparative claims about that culture being more or less cognitively sophisticated than other cultures.

Lastly, the assemblage of material evidence for a past culture may exhibit a range of complexity in its objects at different levels. For example, objects may be complex in how they are made (e.g., copper tools vs. pure flint, or bow and arrow vs. a simple spear) and complex in what they are intended to do (e.g., a bone needle for filigree sewing or a plough for sophisticated agricultural activity). The peak of complexity in the set of material evidence can guide our inference about the past culture's potential for cognitive complexity or cognitive capacity.

Importantly, the first two features or decision heuristics (diversity and necessity) of the DN(C) model can be used as a more general model for calibrating absolute and comparative claims about a past culture. That is, any cultural inference that can be derived from material evidence can be combined with judgments about the diversity and necessity of the objects included. This makes it possible to calibrate (a priori) or confirm (post hoc) claims about a variety of characteristics of a past culture other than its cognition, such as religiosity, value systems, or political perspectives. To investigate claims about these other cultural traits, the only one of the three traits to be replaced in the present model would be the third and final trait that directly evaluates the objects in a set of material evidence for the specific trait in question (i.e., in the present commentary, complexity as a proxy for cognitive capacity).

The proposed model is differentially effective in achieving a better understanding of past cultures for different cultures.

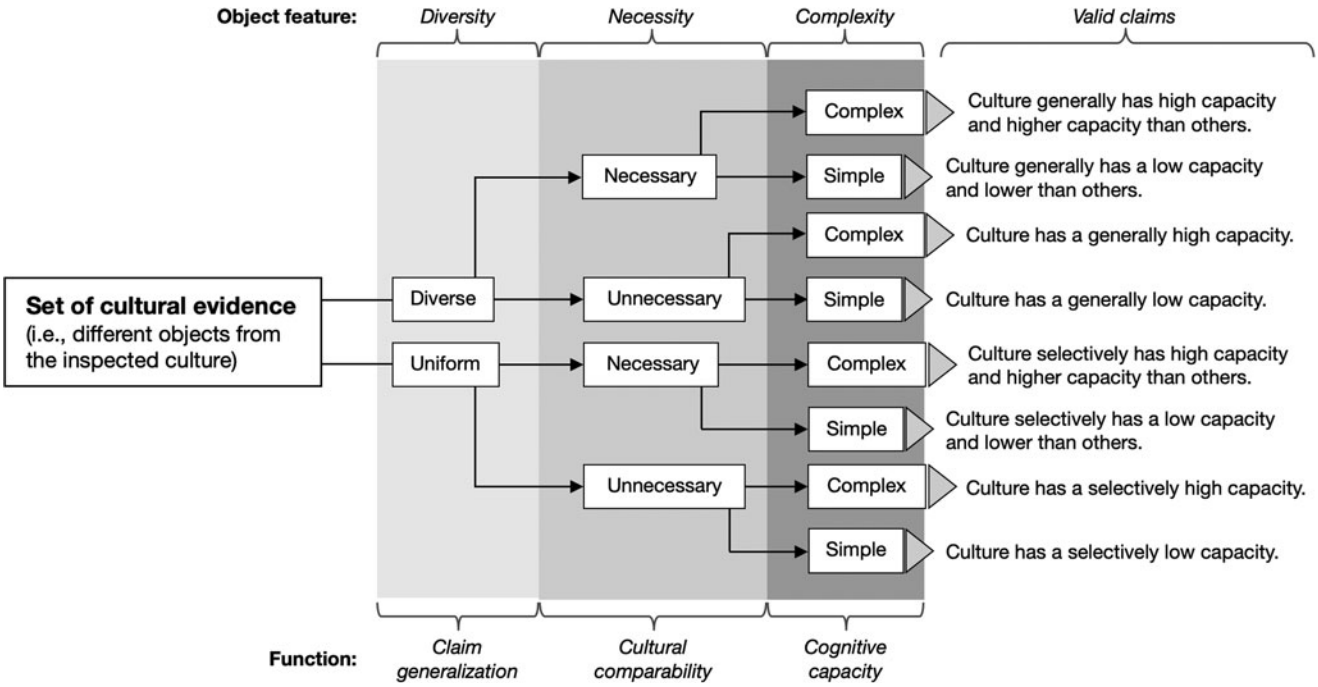

Figure 1 (Grüning and Grüning). Calibration model to navigate claims about absolute and comparative cognitive capacity of a culture.

Most importantly, our object-based model becomes more applicable as the alternative methods that could be used to measure the desired feature claim of that culture become increasingly scarce. For example, for the Mediterranean cultures of classical antiquity, the abundance of surviving architectural, pictorial, epigraphic, and especially literary sources often allows for a more precise assessment of the desired feature claim than the more basic archaeological evidence (e.g., pottery, tools, etc.) alone could provide. We hasten to point out that the DNC model is of considerable relevance to the Middle and Upper Palaeolithic, which is Stibbard-Hawkes's main focus, where there is an almost total lack of other such sources as outlined above.

Stibbard-Hawkes opens up a central discussion about what kinds of evidence and lack of evidence allow for what kinds of (absolute and comparative) claims about past cultures. To make a first productive proposal for a unified framework for calibrating and corroborating such claims, we present the DNC-model, which is based on evaluating two core features of a set of material evidence (i.e., object diversity and necessity) and one feature specific to the cultural characteristic of cognitive capacity (i.e., object complexity). This model allows researchers to propose and discuss which claims about a past culture are robust and which are tentative at best.

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Negative priors and inferences from absence of evidence in cognitive and linguistic archaeology: Epistemically sound and scientifically strategic

Aritz Irurtzun*

CNRS-IKER (UMR 5478), Bayonne, France.
aritz.irurtzun@iker.cnrs.fr
https://iker.cnrs.fr/z-aritz-irurtzun/

*Corresponding author.

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Abstract

The article provides an important warning but its general conclusions should be nuanced: (i) When there is no evidence for it, we should depart from the hypothesis that a species lacks a particular cognitive capacity, and (ii) inferences from absence of evidence can be epistemically sound and scientifically strategic in cognitive and linguistic archaeology.

Stibbard-Hawkes provides an important warning against naively *deducing* from an absence of (positive) evidence E for cognitive trait C, the total absence of C in a given population. He is right in criticizing any proposal that deductively ties absence of C to absence of E: Logically, even if we could reliably establish that $E \Rightarrow C$, that would not entail that $\neg E \Rightarrow \neg C$, and he provides compelling evidence against deducing lack of cognitive modernity for human populations that do not produce enduring evidence of it.

I am very sympathetic to the article's main empirical contribution, and I understand it as an important cautionary note. However, I think that its most general conclusions should be nuanced, in particular in their evolutionary and cross-species comparative prisms: One thing is to assume universality of capacities *within* a species, and a very different one to do it *across* species. As a matter of fact, it seems to me that the adoption of such an overarching prior as the one proposed in the article ("until proven otherwise, all members of at least our genus had comparable capacities" [target article, sect. 16, para. 8]) may amount to a scientific dead end.

To begin with, Popperian conjecture and refutation can only be effective if the conjecture can be refuted with empirical observations, but this will hardly be the case with the hypothesis proposed; no artifact finding in an archaeological setting will show that species S did *not* possess C. Thus, I believe that it is safer and epistemologically sounder to start with the opposite hypothesis ($\neg C$).

Besides, Bayesian epistemology can also help vindicating the possibility of substantive *inductive* inferences from settings where evidence is absent (Howson & Urbach, 1989; Oaksford & Hahn, 2004; Stephens, 2011) – a very common situation in archaeology (Thomas & Darvill, 2022; Wallach, 2019):

1. In order to infer any cognitive capacity C from evidence E, there has to be a causal link between E and C (say, we theorize that it is C that enables E), and therefore the probability of finding E given C must be larger than that of finding E in the absence of C: $Pr(E|C) > Pr(E|\neg C)$. Thus, in Bayesian jargon, finding E in a given archaeological setting *confirms* (Popperian *corroborates*) the plausibility of attribution of C to S. But in logical consequence it also follows that $Pr(\neg E|\neg C) > Pr(\neg E|C)$, and thus $\neg E$ – given certain conditions (see below) – could be taken as *confirming* (positively updating our credence that) $\neg C$.
2. The conditions for an inference from absent evidence depend on a number of factors. One is the causal link between C and E (see points 3 and 4 below). But as the work of Stibbard-Hawkes rightly points out there are also factors like taphonomy and particularities of cultural practices that may cause $\neg E$. To these we should also add our own research (whether we looked deep enough, etc.). If factoring in taphonomy, and so on, we consider that $Pr(\neg E|\neg C) > Pr(\neg E|C)$, and our research efforts were sufficiently accurate but still we find out $\neg E$, then we may be justified in positively updating our belief that $\neg C$. Even more so if our research on S uncovered analogous sets of evidences E' (say, made with the same materials of E, but lacking the characteristics that would make them E), so that we may be justified in inferring that had S produced E, we would have discovered it.
3. We are dealing with cognitive and linguistic archaeology, and the purported evidence is not direct evidence of C, but evidence E that could signal C, *modulo* a range of assumptions about the link between E and C. It goes without saying, the devil is in the details, and the nature of C, E, and of their link ought to be formulated in formally precise (and therefore consequential) propositions, modeling the *strong generative* procedures to go from C to the set of possible E. For instance, a notion such as "symbolism" is too vague (as many species ostensibly display some capacity for "symbolic thought" – see, e.g., Gallistel, 1998, 2011), likewise for any unqualified communicative view of language (as communication is present widely in the animal kingdom [Hauser, 1996; Hauser, Chomsky, & Fitch, 2002], but also among fungi and plants [e.g., Boyno & Demir, 2022]).
4. In this respect, the analysis of the cognitive-computational power allegedly required for particular behaviors (e.g., the generation of recursive linguistic structures, knotting, or complex-patterned art), abstractly analyzed as pertaining to different levels of the *Chomsky hierarchy* may be a route to explore (cf. Camps & Uriagereka, 2006). If – and this is a big "if" – we could reliably ascribe particular behaviors/productions to a well-defined cognitive capacity (say, the capacity to compute context-sensitive grammars [producing Type-1 formal languages]), then evidence E of a particular behavior by species S could be taken as *confirming* the possession of C by S. Consequently, and given the necessary conditions, $\neg E$ could also be justifiably taken as (probabilistically) confirming $\neg C$.

To conclude, a certain homogeneity of traits is a core assumption for intra-species groupings; we can expect C to be "universal" across the individuals conforming a species (e.g., trichromatic vision, or the capacity for context-sensitive symbolic computations in humans). But in the absence of the relevant evidence, this cannot be extended to inter-species or inter-taxa groupings. In cross-species comparison I think that it is safer to depart from the hypothesis that, say, *Homo antecessor* or zebra finches lack C (especially when C is a rather unique trait), and then look for evidence of C (cf. i.a. Fitch & Hauser, 2004; Beckers, Bolhuis, Okanoya, & Berwick, 2012) than just be satisfied by assuming that they have C and stop further research. Assuming as Stibbard-Hawkes proposes a substantive positive prior could not, by essence, be negatively updated. That is, if we depart from the hypothesis that extinct species S did possess cognitive property C, then there can be no positive evidence E that will disproof (negatively update) our hypothesis.

In sum: We should lower our priors that $\neg C$, but not invert them to C.

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Revising the null model in language evolution research

Svetlana Kuleshova[a,b]*, Michael Pleyer[a], Johan Blomberg[c], Marta Sibierska[a] and Sławomir Wacewicz[a]

[a]Department of Experimental Linguistics, Centre for Language Evolution Studies, Nicolaus Copernicus University in Toruń, Toruń, Poland; [b]Department of Anthropology, ArScAn-Équipe AnTET (UMR 7041), CNRS, Université Paris Nanterre, Nanterre, France and [c]Division of Linguistics, Phonetics and Cognitive Semiotics, Center for Languages and Literature, Lund University, Lund, Sweden
40010189@parisnanterre.fr
pleyer@umk.pl
johan.blomberg@ling.lu.se
sibier@umk.pl
wacewicz@umk.pl
https://cles.umk.pl/

*Corresponding author.

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Abstract

We comment on the consequences of the target article for language evolution research. We propose that the default assumption should be that of language-readiness in extinct hominins, and the integration of different types of available evidence from multiple disciplines should be used to assess the likely extent of the realization of this readiness. The role of archaeological evidence should be reconsidered.

The target article argues that the disciplines drawing on the archaeological record should reformulate their null hypothesis. This should apply to language evolution, where it is still common to assume the absence of language in the absence of hard artefactual evidence – an inferential strategy that Stibbard-Hawkes clearly shows to be invalid. In order to change this, we propose that (a) based on biological continuity, we should start from the assumption of language-readiness in extinct hominins, and (b) we should integrate the existing evidence to assess the likely extent of the realization of this readiness and/or to question the null hypothesis.

The explanans for language evolution remains highly influenced by overall ontological, epistemological, and methodological assumptions, as is captured by Jackendoff's (2010) slogan: "your theory of language evolution depends on your theory of language." For example, in the field of archaeology, "language" is often tacitly assumed to be akin to modern language (for a discussion, see, e.g., Botha, 2010), likely due to the fact that modern humans are our only point of reference, and by that token, an inevitable starting point of comparisons with the extinct species. "Language," however, can be construed in a variety of widely different ways, which – as our earlier work shows (Wacewicz, Żywiczyński, Hartmann, Pleyer, & Benitez-Burraco, 2020) – form a broad family-resemblance mosaic that simply cannot be reduced to a single "correct" definition. In short, speaking of "language" *sensu* largo is often unhelpful, and we need to use more precise terminology.

A particularly useful distinction is that between the biological or "somatic" readiness for language and the non-biological scaffolding, the former understood as a set of organism-internal traits transmitted mostly through biological inheritance that are necessary but not sufficient to develop language, and the latter as a set of largely organism-external variables – social, motivational, cultural, etc. – that make it possible to develop language based on the former. This is already foreshadowed in Stibbard-Hawkes' distinction between "somatic" and "cultural" models and is in fact present in standard language evolution models. A prime example is Arbib's (2012) "language-ready brain," which captures the idea of a minimal cognitive endowment necessary to use a language-like communication system (cf. also, e.g., Burkart, Martins, Miss, & Zürcher, 2018, for the importance of biologically grounded adaptations for cooperativity as another *sine qua non*). But more generally, most scenarios endorsing the hypothetical stage of protolanguage (e.g., Scott-Phillips & Kirby, 2010) assume a relatively greater role of biological evolution in molding a hominin phenotype that becomes capable of using protolanguage, and after that, a relatively greater role of cultural evolution or other external factors (e.g., "language-ready social settings," Pleyer & Lindner, 2014). The difference between the internal versus external conditions for language has non-trivial consequences. For example, they differ in the rate of change, with the external scaffolding being relatively faster to change, but the evolution of biological language-readiness being relatively slower-paced (Chater, Reali, & Christiansen, 2009). Biological language-readiness can thus be reasonably assumed to have a deep past; hence, we propose that based on biological continuity, it is more parsimonious to assume its presence rather than absence (of course as a default defeasible with evidence).

With this new null hypothesis in mind, the role of the archaeological evidence should also be reassessed. The target article demonstrates how little of the actual material culture would be preserved from modern hunter-gatherer societies, documenting the dangers of "negative" inferences from archaeological material, that is, from the absence of material record to the absence of the underlying cognition. In light of this, we see archaeological evidence as having a primarily confirmatory role, that is, mandating inferences from its presence but not absence: archaeological material should aim to confirm the likelihood of the realization of the language capacity. When this likelihood is small, prehistoric hominins are not denied the capacity *per se* (or even its realization, as it might simply not be detectable through archaeological remains). This leaves a "gray zone" in which the likelihood of language use in hominins can be probabilistically evaluated with

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non-absolute but increasing certainty, something that is impossible in dichotomous thinking about the presence versus absence of language.

More generally, we propose that different evidence can contribute to assessing different parts of the new null model and its consequences. The type of evidence most relevant to the assessment of our proposed null – that is, that as a default, extinct hominins should be assumed to be language-ready – is mostly the anatomical, genetic, fossil, and so on, evidence informative about the extent of biological continuity. On the other hand, the totality of available interdisciplinary evidence must be used to estimate the potential use of language by these hominins. Language evolution research is by nature fundamentally interdisciplinary (e.g., Christiansen & Kirby, 2003; Fitch, 2010), meaning that many disciplines play important roles in providing pieces to the puzzle of language evolution (Mithen, 2024). For example, research in comparative cognition as well as animal cognition and communication have an important role in specifying the evolutionary platform on which the evolution of the language-ready brain built on (e.g., Berthet, Coye, Dezecache, & Kuhn, 2023; Tomasello, 2008; Zhang & Pleyer, 2024). Further, experimental research in the cultural evolution of language has important contributions to make in specifying the social and cognitive dimensions that support the emergence of communication systems (Delliponti *et al*., 2023; Müller & Raviv, 2024; Nölle & Galantucci, 2023; Roberts, 2017; Tamariz, 2017). However, the target article serves as an important reminder that we have to determine which strands of evidence from different disciplines can constrain hypotheses on language evolution (Johansson, 2005) and how they can be used to advance causal hypotheses that can be empirically investigated (Roberts *et al*., 2020). Most importantly, Stibbard-Hawkes's findings reiterate that we have to critically re-assess which inferences can be drawn from existing evidence not only for archaeology, but for all disciplines involved in investigating the evolutionary emergence of language (e.g., Botha, 2020; Botha & Everaert, 2013).

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Competing interest. None.

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Beyond the binary: Inferential challenges and solutions in cognitive archaeology

Cheng Liu[a]* and Dietrich Stout[a,b]

[a]Department of Anthropology, Emory University, Atlanta, GA, USA and [b]Center for Mind, Brain & Culture, Emory University, Atlanta, GA, USA
cheng.liu@emory.edu
dwstout@emory.edu
https://raylc.github.io/
https://anthropology.emory.edu/people/bios/stout-dietrich.html

*Corresponding author.

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Abstract

We welcome Stibbard-Hawkes's empirical contributions and discussion of interpretive challenges for archaeology, but question some of his characterizations and conclusions. Moving beyond critique, it is time to develop new research methods that eschew simplistic modern/premodern binaries. We advocate an inductive, probabilistic approach using multiple lines of evidence to infer the causes and consequences of behavioral variability across time and space.

> 'Modern' is thus doubly asymmetrical: it designates a break in the regular passage of time, and it designates a combat in which there are victors and vanquished. If so many of our contemporaries are reluctant to use this adjective today, if we qualify it with prepositions, it is because we feel less confident in our ability to maintain that double asymmetry: we can no longer point to time's irreversible arrow, nor can we award a prize to the winners (Latour, 1993, p. 10)

We applaud Stibbard-Hawkes's cutting-edge analysis of data from three African foraging communities and his consideration of its implications for archaeology. Nonetheless, we are concerned that his broader critique employs straw-man arguments that misrepresent the state of the field. In particular, Stibbard-Hawkes's analysis of logical errors in cognitive archaeology (target article, sect. 4) and subsequent discussion downplays widespread critiques of the "behavioral modernity" construct over the past two decades, including McBrearty and Brooks (2000) and many others (Kissel & Fuentes, 2021; Kuhn, 2021; Meneganzin & Currie, 2022; Shea, 2011), some of which he cites in section 3. This amplifies unilinear and teleological views of cognitive evolution and erroneously portrays them as consensus. We suggest it is time to move from critique to the development of new approaches not organized around sterile simple/complex or modern/pre-modern binaries.

We advocate (e.g., Stout & Hecht, 2023) a more particularist approach to studying the cognitive processes behind the production, reproduction, perception, and variation of specific material cultural evidence (e.g., geometric engravings, cave painting, pigment, compound tools, etc.) by integrating experimental, ethnographic, comparative, and archaeological evidence. We agree with Stibbard-Hawkes that such investigations should not be framed around an assumed "null hypothesis" of cognitive primitiveness. We instead suggest (e.g., Stout, Rogers, Jaeggi, & Semaw, 2019) an inductive and probabilistic approach (c.f. consilience, Inference to Best Explanation [Killin & Pain, 2021; Stock, Will, & Wells, 2023]). Our own work focuses on stone toolmaking, but Tylén et al. (2020) provide a relevant example. Using Blombos and Diepkloof engravings as stimuli, they found that design changes over 30,000 years made these signs more salient, memorable, and easier to reproduce. This provides positive evidence for the use of these signs in an evolving communicative system but does not warrant conclusions about the presence/absence of symbolic cognition. Ethnographic studies can help us understand possible social contexts for such sign systems, as briefly considered in section 10 of the target article.

Stibbard-Hawkes argues that cognitive archaeologists routinely treat absence of evidence as evidence of absence. We agree this can be a problem, but not that archaeologists are generally so simplistic. As recently reviewed by Wallach (2019), archaeologists often use the absence of evidence in a probabilistic way. This is logically valid and consistent with the move away from a "null hypothesis" approach. Kelly, Mackie, and Kandel (2023) demonstrate the utility of such *argumentum ad ignorantiam* to identify behavioral patterns in need of explanation. Stibbard-Hawkes criticizes their "provisional assumption" that symbolic expression in a population would have left some material trace, but we see this as a disagreement about probabilities rather than a logical fallacy. Importantly, Kelly et al. (2023) provide a balanced discussion of possible factors other than cognition that might contribute to the observed pattern. This is productive and can lead to further research.

This also applies to experimental evidence. Stout and Hecht (2023, p. 6) review the epistemology of experimental cognitive archaeology, emphasizing that it is not possible to use modern data "to demonstrate the presence/absence of particular neuroanatomical structures [or] functions" at particular points in the past. Rather, the objective is to characterize patterns in the expression of particular capacities in order to identify the somatic, social, and ecological factors that favor their expression (i.e., evolutionary causation broadly construed). For example, Stout and Chaminade (2012) wrote that Lower Paleolithic toolmaking studies to date had not found "significant activation of 'ventral stream' semantic representations" suggesting that this behavior is not particularly demanding of such representations. They note that this pattern could simply reflect experimental design, but that "if this trend continues" it might suggest that such semantic representation "evolved later and/or in a different context." This is a probabilistic argument about likely selective contexts rather than an attempt to date the emergence of a particular semantic capacity (as is unfortunately suggested by the highly selective quote in the target article). Rather than attacking straw men, we propose that cognitive archaeology should focus its energy on identifying potential causal pathways leading to, and likely evolutionary consequences arising from, the expression of behaviors across time and space, rather than attempting to date the "appearance" of particular capacities along a unilinear sequence leading to modern humans. Evidence presented by Stibbard-Hawkes can contribute to this project.

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Not just symbolism: Technologies may also have a less than direct connection with cognition

Annemieke Milks*

Department of Archaeology, University of Reading, Reading, UK
a.g.milks@reading.ac.uk; https://www.reading.ac.uk/archaeology/staff/dr-annemieke-milks

*Corresponding author.

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Abstract

I expand Stibbard-Hawkes' exploration of symbolism and cognition to suggest that we also ought to reconsider the strength of connections between cognition and technological complexity. Using early weaponry as a case study I suggest that complexity may be "hidden" in early tools, and further highlight that assessments of technologies as linear and progressive have roots in Western colonial thought.

Stibbard-Hawkes' target article is a welcome critique of models on the interplay between material culture and cognition. The paper rightly focuses primarily on symbolism and its materiality (or often lack thereof), paying particular attention to taphonomy and its challenges for the archaeological record. Stibbard-Hawkes' analysis advances a discourse that has tended to be data-poor, and hence largely theoretical in nature. He does so by providing quantitative and empirical ethnographic evidence that symbolic behaviour may have left archaeological signatures only in exceptional circumstances.

In the technological realm we have the same taphonomic concerns, particularly around early wooden tools such as expediently made tools like wooden clubs used by chimpanzees to crack nuts, and the wooden spears carefully crafted by hominins in the Middle Pleistocene. I propose to extend Stibbard-Hawkes' argument by suggesting that a direct relationship between technological complexity and "modern" cognition is not always evident. Early weaponry provides a useful case study.

I suggest that (1) we may not always fully recognise or understand design features of tools when we make an "at-a-glance" assessment with our Western lens; (2) we may also be failing to account for social complexity underpinning use of "simple" tools; and (3) placing technology on a progressive ladder has deep and problematic roots in Western colonial thinking.

Technological complexity is variably defined in the archaeological literature. It is often used in contrast with "simple," one-piece tools including unhafted stone tools and untipped wooden spears. In human evolutionary studies, technological complexity can refer to tools having more than one component (e.g., Hoffecker, 2018), as in "composite" or "compound" tools. Alternatively, it can involve listing and categorising the number of actions and/or production steps (Haidle, 2009; Leder et al., 2024; Wadley, Hodgskiss, & Grant, 2009). With reference to weaponry, complexity can refer to composite weapons, such as a spear with a hafted stone point (e.g., see Lombard & Haidle, 2012) or it can represent complexity of function – as in mechanically projected weapons (Shea & Sisk, 2010). Typically this is in contrast with so-called "simple" weapons, that is, those consisting of a single piece, and/or which are launched by hand. Technological complexity is often linked with more highly evolved cognition. Within weaponry studies, linear models have often shown innovations occurring through time, and imply that "simple" weapons are replaced by more complex ones, whereas all of these weapons have continued to be used by our own species.

Complexity of manufacture and design

The earliest known archaeological weapons are wooden spears and throwing sticks, produced by late *Homo heidelbergensis* or early Neanderthals. Haidle (2009) shows that classing wooden spears as "simple" underestimates the many steps and mental processes involved in manufacturing them. Although these objects may look like mere "sharpened sticks," recent detailed analyses of examples from Schöningen (Germany) provide evidence of multiple steps in woodworking alongside a suite of features that show rich awareness of material properties and aerodynamics (Leder et al., 2024; Milks et al., 2023).

Socio-cultural complexity

Arguably, researchers of subsistence technologies, myself included, can over-focus on the practical and under-focus on socio-cultural aspects. This may in turn result in failure to consider complexity beyond the tool itself. Even though spears are often characterised by Western scholars as inferior to mechanically projected weapons, spear hunting is considered *by those who practice it* to be a particularly "complex skill" (Lew-Levy et al., 2021). Learning to spear hunt begins in early childhood, and teaching it is classed as "costly" (Lew-Levy et al., 2022). Particularly "costly" forms of teaching, like instruction involving language, could have evolved as a means of transmitting cumulative, complex knowledge such as that required for learning how to hunt, albeit with technologically "simple" weapons (Lew-Levy et al., 2022).

The Western lens

Stibbard-Hawkes points out that disparagement of small-scale societies is intimately intertwined with ideas of advances in technologies. The absence of composite and mechanically projected weapons played a significant role in portrayals by twentieth-century scholars of Aboriginal Tasmanian people's cognitive capacities. Noetling (1911) suggested that their failure to add a stone point to a wooden spear indicated the lack of a "modern" mind. Decades later Jones (1977) wrote that their simple technocomplex portended a "strangulation of the mind" strongly implying that the population was "doomed" to fail anyway, thereby justifying their displacement and genocide by white settlers.

Models that are not linear or progressive already exist as frameworks within which to consider variability and innovation of material culture on human evolutionary timescales. For example, Shea and Sisk (2010) make a case that it is unnecessary to highlight differences in cognition when exploring variability in hunting technologies, with time-budgeting and energetic constraints providing alternative explanations. Haidle et al. (2015, p. 53) propose a model which "does not imply a progressive ladder…but focuses on expansion of cultural capacities that extends the behavioral options and repertoire while retaining the possibilities of earlier states." As well as evolutionary-biological factors, their model highlights the importance of historical-social and ontogenetic-individual dimensions.

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I propose that so long as it remains unproven that increasing technological complexity tracks neatly and directly with cognition, we need to consider critically the roots of these models and their underlying assumptions. The adoption of at least an agnostic null hypothesis, if not a "cognitively modern" hypothesis, as proposed by Stibbard-Hawkes, is supported by this brief examination of the technological domain.

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Are we jingling modern hunter-gatherers and early *Homo sapiens*?

John Protzko

Psychological Science, Central Connecticut State University, New Britain, CT, USA
protzko@gmail.com
https://sites.google.com/view/assumptionlabccsu/home

*Corresponding author.

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Abstract

Using modern hunter-gatherers to infer about early *Homo sapiens* only works if at least (a) modern hunter-gatherers represent an unbiased sample of humanity, and (b) modern hunter-gatherers act in ways similar to the behavior of early *Homo sapiens*. Both of these are false, leading to the problem of whether we can draw conclusions about early *Homo sapiens* from modern hunter-gatherers.

The author did a good job defending their argument that modern hunter-gatherers do not *necessarily* leave evidence of their advanced cognitive abilities, the field assumes no advanced cognition without physical evidence, and this Primitive null largely relies on the absence of evidence. The author's argument, however, rests on the assumption that we can draw conclusions about early *Homo sapiens* from modern hunter-gatherers.

The jingle fallacy is the error of assuming two things with the same name are similar (Thorndike, 1904, crediting Aikins, 1902). By referring to both early and modern people with the same "hunter-gatherer" term, we may end up believing that the behavior of one is a stand-in for the behavior of the other.

There are at least two requirements for modern hunter-gatherers to be richly informative for reconstructing the behavior, psychology, culture of early *Homo sapiens*. First, modern hunter-gatherers would need to represent an unbiased sample of *Homo sapiens*. Second, the behaviors of modern hunter-gatherers would need to be representative of the behaviors of early *Homo sapiens*. Both of these requirements are not met.

Early *Homo sapiens* were composed of groups of individuals. Some of those individuals left their usual territories and explored the world, built cities, developed writing, mastered smelting. Over 200,000 years, humans have urbanized—while an infinitesimally small number of humans have stayed put and remained hunter-gatherers.

Early *Homo sapiens* traveled the entire planet, sailing into the Mediterranean islands 130,000 years ago (e.g., Watrous, 1994; see also Strasser et al., 2010), crossing the Beiring Strait more than 20,000 years ago (e.g., Bennett et al., 2021), and reaching down to the bottom of the Americas some 9,000–7,000 years ago (e.g., Civalero & Franco, 2003). This is not the behavior of a species that stays put but modally is one that moves. Modern hunter-gatherers, however, especially the ones highlighted by Stibbard-Hawkes (Hadza, G//ana, Mbuti), have stayed put.

Furthermore, the majority of the human species have urbanized (Ritchie & Roser, 2018)—modern hunter-gatherers have specifically resisted urbanization. Tanzanians who live near the Hadza have urbanized. Botswanans who live near the G//ana have urbanized. Congolese who live near the Mbuti have urbanized. But not modern hunter-gatherers.

Modern hunter-gatherers are humans who have stayed put, resisted urbanization, and kept the old ways by choice. If members of a modern hunter-gatherer tribe decide to leave and live in the urbanized world, they are not part of data collection with current members of their old modern hunter-gatherer tribes. This suggests a large sampling bias among humanity for who is, versus is not, a modern hunter-gatherer.

If we make the simple assumption that it is not random who chooses to remain in the hunter-gatherer lifestyle and who chooses to leave or urbanize (both historically and currently), it becomes apparent that modern hunter-gatherers are not

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necessarily a window into early *Homo sapiens* but instead are a very unique population that in no way is representative of humanity past or present. It is a case of a self-selected sampling bias of humanity.

The authors cite evidence that modern hunter-gatherers do not engage in many of the practices early *Homo sapiens* did: "Contemporary foragers …[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 (Henshilwood and Dubreuil 2009; Klein 2017; Mellars 2005; Wadley 2021) for past behavioural complexity" (target article, Sect. 4, para 1). Such practices are all things early *Homo sapiens* did that modern hunter-gatherers do not.

Focusing on their own participants: "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" (target article, Sect. 10, para 2). The author shows in a very convincing way why the modern hunter-gatherers do not engage in many of these practices, but it still means modern hunter-gatherers are acting in ways that are different from the ways we know early *Homo sapiens* acted.

So on both fronts, non-representative sampling bias and differential behavior, modern hunter-gatherers are not representative of current or early *Homo sapiens*. We ask: Why is the behavior of modern hunter-gatherers insightful to reconstructing the behavior of early *Homo sapiens*?

Modern hunter-gatherers are an extremely self-selected segment of humanity. They do not act like the majority of modern humans, they do not act in many of the ways of early humans either. Modern hunter-gatherers are humans like the rest of us, but they are not more authentically so. They may not be a window into the ways of early *Homo sapiens*. Indeed, among early *Homo sapiens*, those who left the savannahs and traveled the world and built cities were no less authentically human than those who kept the old ways.

Using modern hunter-gatherers may just be where the light is—because we can observe their behavior where we can only observe the outcomes of some early *Homo sapiens* behavior. But they are likely not the window into the past we hope they are. In this way, we ask the author to justify why the evidence they present about modern hunter-gatherers should be taken as evidence for what early *Homo sapiens* did.

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The cognitive and evolutionary science of behavioural modernity goes beyond material chronology

Andoni S. E. Sergiou[a]* and Liane Gabora[b]

[a]Human Behaviour and Cultural Evolution Group, Centre for Ecology and Conservation, University of Exeter (Penryn Campus), Penryn, Cornwall, UK and [b]Department of Psychology, University of British Columbia (Okanagan Campus), Kelowna, BC, Canada
as1488@exeter.ac.uk
liane.gabora@ubc.ca
http://andonisergiou.com
https://gabora-psych.ok.ubc.ca

*Corresponding author.

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Abstract

Stibbard-Hawkes' taphonomic findings are valuable, and his call for caution warranted, but the hazards he raises are being mitigated by a multi-pronged approach; current research on behavioural/cognitive modernity is not based solely on material chronology. Theories synthesize data from archaeology, anthropology, psychology, neuroscience, and genetics, and predictions arising from these theories are tested with mathematical and agent-based models.

We concur with Stibbard-Hawkes' call for caution when using past material culture as an evolutionary or cognitive yardstick, though in our view the paper does not pose a significant challenge to prevailing views and approaches to (what is somewhat controversially referred to as) "behavioural/cognitive modernity". Whether or not a given population can be decisively said to have crossed this threshold, cognitive modernity *did* evolve, and much research aims merely to piece together how it came about. We agree with Stibbard-Hawkes that it is not the universal expression of symbolic culture that defines humans but our propensity to reinvent it, and that cognitive propensity still calls for an evolutionary explanation – with or without a reliable archaeological signature.

Current research on "behavioural modernity" has moved on from the kind of simple inferences once made from material chronologies that Stibbard-Hawkes challenges (Meneganzin & Currie, 2022). In the time since these concerns with archaeological inference were first raised by McBrearty and Brooks (2000), explanations of behavioural modernity have broadened from innate neurocognitive adaptations to encompass demographic, ecological, and cultural evolutionary factors, making current efforts subtler and more multi-pronged than their characterization in the target paper. Much research now focuses on identifying adaptive packages of features typifying contemporary human populations (Hill, Barton, & Hurtado, 2009; Migliano & Vinicius, 2022), including neural, social, and ecological mechanisms (Derex & Boyd, 2015; Migliano et al., 2020; Singh et al., 2021), as well as factors pertaining to life history, cooperation, and social and individual learning strategies (Herrmann, Call, Hernàndez-Lloreda, Hare, & Tomasello, 2007; Muthukrishna, Doebeli, Chudek, & Henrich, 2018; Osiurak, Claidière, & Federico, 2023; Street, Navarrete, Reader, & Laland, 2017). This research aims for converging evidence from multiple disciplines. To this end, the mechanisms and adaptive context of behavioural modernity in contemporary foragers may provide a more useful test of contemporary theory than material assemblages. For example, one such line of interdisciplinary research develops theories synthesizing data from archaeology, anthropology, neuroscience, and genetics (Chrusch & Gabora, 2014), and tests these theories using mathematical models (e.g., Gabora & Kitto, 2013; Gabora & Steel, 2017, 2020a, 2020b), and agent-based models (e.g., Gabora & Smith, 2018). This line of research points to a two-stage model, wherein (1) increased brain size enabled finer-grained mental representations and streams of representational redescription, and subsequently, (2) onset of *contextual focus*: The capacity to shift between different modes of thought enabled integration of mental contents across contexts and domains (Gabora & Smith, 2019). By endowing neural network-based artificial agents with representational redescription and contextual focus, and observing the hypothesized increases in the fitness and diversity of cultural outputs in different population structures, we gain a richer picture of how archaeological findings may align with cognitive transitions (Gabora & DiPaola, 2012). Thus, current behavioural/cognitive modernity research goes well beyond simple inferences from material chronologies. We add that, at this point, it remains an open question whether there *is* any universally applicable distinction to be made between archaic and modern.

A related issue is that the problems with material chronologies highlighted in this target paper makes validating the predictions of demographic and cultural evolutionary models as challenging as cognitive evolutionary models, as many of these posit similar phase transitions in evolving cultural and semiotic complexity in the archaeological record (Henrich, 2004). For example, theories of behavioural/cognitive modernity that emphasize changes in between-group migration rates and population densities predict changes in the retention and production of new forms of cultural variation, including symbolic culture (Derex, Perreault, & Boyd, 2018; Grove, 2016; Powell, Shennan, & Thomas, 2009). We note that predictor variables related to demography and cultural evolution are not included in the target paper.

Stibbard-Hawkes claims that "contemporary foragers are just as cognitively sophisticated as other contemporary human populations" (sect. 4, para. 1), but the article does not provide sufficient evidence to assess this claim. Indeed, cognitive sophistication is not uniform even amongst contemporary human populations. (For example, individuals from small-scale foraging societies outperform those from industrialized societies at recognizing Müller-Lyer illusions, whereas those without formal education fair worse at inductive logic than those with [Henrich, Heine, & Norenzayan, 2010; Nell, 1999].) Moreover, even in the absence of significant neurobiological differences (nature), diversity in cognitive sophistication may result from differences in individual learning experiences and culturally transmitted knowledge and beliefs (nurture, see Heyes, 2020), as well as context-dependent differences in creative or analytic thought trajectories culminating in new knowledge and beliefs. This last can be referred to as *nous*, an ancient Greek concept that refers to intellect, understanding, or reason. Thus, cognitive phenotypes can be said to be the product of nature, nurture, and nous (Gabora & Robertson, in press). The idiosyncrasies by which individual instances of nous operate add unique historically dependent variation into the repertoires of populations that are not reducible to nature or nurture; while nature and nurture provide the raw materials, nous forges these raw materials into new ideas. This distinction between "raw materials" and "derived" contents (i.e., nous) arises naturally in an area of network science known as Reflexively Autocatalytic Foodset-generated (RAF) networks, and this is one reason RAF networks have been used to model transitions in cognitive evolution (Gabora & Steel, 2017, 2020a, 2020b). In short, further research would be needed to assess whether contemporary foragers differ from other contemporary human populations with respect to either nurture or nous, and even differences because of nature could have arisen due to the Baldwin effect.

In conclusion, a full understanding of behavioural modernity and its evolution requires an interdisciplinary scientific approach that encompasses nature, nurture, and nous, and this approach is alive and well, despite the challenges of material taphonomy. We close with a final point regarding the target paper. If utilitarian tools are disproportionately likely to contain archaeologically traceable components, as the author claims, that suggests that our ancestors may have been much more creative than what we can surmise from the existing archaeological record.

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Inferences from absences

Kim Sterelny*

School of Philosophy, Research School of the Social Sciences, Australian National University, Acton, Canberra, Australia
Kim.Sterelny@anu.edu.au

*Corresponding author.

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Abstract

Stibbard-Hawkes shows that cultures using material symbols might well not leave traces of that practice in the archaeological record. The paper thus poses an important challenge: When is absence of evidence evidence of absence? This commentary uses behavioural ecology to make modest progress on this problem.

Stibbard-Hawkes has shown that despite regular acknowledgement of gaps and bias in the archaeological record, theorists of the human past, me included, have too readily reasoned from absent evidence. In particular, we have accepted that the lack of evidence for symbolic technology in the Late Pleistocene (excepting the ambiguous case of ochre) is evidence that pre-Late Pleistocene hominins did not use such technologies; in some cases even inferring that they lacked the cognitive capacities to use material symbols. Trace erosion can always cause false negatives, but Stibbard-Hawkes' ethnographic data (admittedly, only African data) shows that symbolic technology is particularly likely to erode; particularly subject to the risk of false negatives.

The paper thus poses an important methodological challenge: In archaeological contexts, when can we infer from lack of evidence for X to the lack of X? The answer surely cannot be: Never. We have very good reason to believe, for example, that Late Pleistocene hominins did not live in towns and villages (or work metal); a secure conclusion based on lack of evidence for settled lives (or metal working). But what makes this inference sound? I will explore this through a less extreme example. Consider Acheulean tool using communities between about 1 mya and 800 kya. This region of space and time saw the emergence both of more complex and symmetrical Acheulean tools (Kuhn, 2020) and of very large-brained hominins, with Heidelbergensis-grade hominins encephalisation overlapping the range of modern hominins (Klein, 2009). But despite the emergence of enhanced knapping skills and the first direct evidence of domesticated fire (Alperson-Afil, Richter, & Goren-Inbar, 2007), there is no evidence of hafted tools. I suggest that this is good evidence that, minimally, hafted tools were not regularly part of these hominins' technical repertoire and, more strongly, that they lacked the capacity to haft tools.

The following considerations support this analysis: (i) From 1 mya on, sites preserving a lithic signature are found over a wide range of regions and habitats: We are not sampling just a small fraction of hominin subsistence economies from this period; (ii) while hafted tools (in general) require more time, materials, and skill to make, theoretical considerations suggest that this would be profitable over a broad range of environmental conditions.

Hafted tools bring mechanical advantage and safety (by placing distance between the working component of the tool and the operator). I know of no formal behavioural ecology models exploring these economics, but I predict that such models would show a clear hafting profit. (iii) Theoretical considerations are supported by ethnographic data: Hafted tools are used ubiquitously, even by foragers under selection for simple, lightweight generalist tools, like those of the Australian Western Desert (Gould, 1980). (iv) While many hafted tools are made entirely of perishable materials (some bow/arrow designs), a wide range of hafted tools have resistant, identifiable components (spears, javelins, arrows, knives, denticulate tools).

The moral: We can trust absence of evidence as (defeasible) evidence of absence when (a) an archaeological landscape has been reasonably well sampled; (b) we have independent evidence that if a capacity was available to agents in that landscape, they would have had incentives to exercise that capacity: The inference is more robust if the incentive is strong, and not tied to a specific constellation of factors within that landscape; (c) if the capacity were exercised with some regularity, at least some traces would be archaeologically visible.

Can we export considerations of this kind to material symbols? Not so well, as function does not constrain material substrate to the same degree as it does with subsistence technologies. There are more degrees of freedom, but perhaps to some degree. The most persuasive accounts of the function of material symbols see them as signals of social identity and role, becoming important in denser social contexts (see, e.g., Kuhn, 2014; Kuhn & Stiner, 2007; McDonald & Harper, 2016). In such contexts, individual interactions become mediated by signals of identity and role, rather than solely by direct personal knowledge, and social aggregates signal rights of place and cohesion to one another.

Given this, the most plausible absence of evidence as evidence of absence is perhaps coastal South Africa between about 150 kya and 100 kya. This archaeological landscape has been reasonably well sampled and has been argued to be a refuge area (in part because of coastal resources) in Late Pleistocene aridity pulses (Marean, 2011; Marean, 2016). If so, it may well have had threshold densities, perhaps not in residential groups, but of densely networked groups, with their potentials for conflict and cooperation. Geographically widespread ethnographic report suggests that shells are often used as a signalling medium; and in identifiable ways, even at some cost. They were indeed so used in Southern Africa somewhat later. We could not reasonably conclude that the peoples represented by Pinnacle Point material culture did not use material symbols. But perhaps we can conclude that they did not use material symbols for the purposes to which shell-based signals are well adapted (Kuhn & Stiner, 2007). Shells are durable (much more so than, say, seed pods) and come in varieties, such that the instances of a specific variety are very similar to each other, while contrasting with others. This makes it possible to use them in complexly patterned, precise, low amplitude signals within extended social networks in which agents shared common cultural norms, but where it is not true that everyone knows everyone well. We might infer that the social world of South Africa before about 100 kya was simpler and more fragmented than it became, below a threshold of signal-mediated social interaction. This inference is less secure than that to an Acheulean without handles, given the looser relationship between function and form; that evidence for social density is difficult to read, and that we do not know the density thresholds above which within-group signals become important. But it has some traction.

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All that glitters is not gold: The false-symbol problem in archaeology

Claudio Tennie[a]* and Ronald J. Planer[b]

[a]Faculty of Science, Working Group Early Prehistory and Quaternary Ecology, University of Tübingen, Tübingen, Germany and [b]School of Liberal Arts, University of Wollongong, Wollongong, Australia
claudio.tennie@uni-tuebingen.de
rplaner@uow.edu.au
https://sites.google.com/view/claudiotennie
https://scholars.uow.edu.au/ronald-planer

*Corresponding author.

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Abstract

Stibbard-Hawkes forcefully alerts us to the pitfall of false-negative reasoning in symbolic archaeology. We highlight the twin problem of false-positive reasoning in what we call the "false-symbol problem." False symbols are intuitively special entities that, owing to their non-utilitarian nature, invite symbolic interpretation. But they are not symbolic. We link the false-symbol problem to work in comparative primate cognition, taking "primate art" as our main example.

The job of archaeologists is often signal detection, that is, to correctly judge the presence or absence of a target phenomenon based on noisy archaeological data. As such, two types of errors are possible: False positives and false negatives. In his article, Stibbard-Hawkes vividly illustrates the threat of one type of false-negative reasoning for symbolic archaeology, providing strong empirical support for the view that, in Moffett (2013)'s words, "many of the symbols employed by recent hunter-gatherers would leave little or no archaeological signature." In this commentary, we extend Stibbard-Hawkes' analysis by elaborating on the corresponding problem of false-*positive* reasoning in the symbolic context. Specifically, we focus on the problem of *false symbols* – intuitively special entities that are judged to be symbolic in some broad sense, but which are not. The false-symbol problem is distinct from the more familiar one of interpreting possible indirect evidence of symbolic behaviour, for example, ochre processing at certain Middle Pleistocene sites. There, the issue is that the evidence might have been produced via non-symbolic, utilitarian behaviours (e.g., skin protection). In contrast, as we explain below, false symbols generally have no clear-cut connection to utilitarian behaviour, yet they are still non-symbolic. False symbols are prototypically both non-utilitarian *and* non-symbolic.

The false-symbol problem is thrown into sharp relief by cultural evolution work in comparative cognition. Non-human great apes ("apes," hereafter) can individually develop certain *utilitarian* behaviours that at first seem to require cultural access, plus human-like types of cultural transmission. However, as Stibbard-Hawkes acknowledges, the fact that these behaviours can develop individually (in at least some individuals) makes them lie instead within their *zone of latent solutions* (Tennie, Braun, Premo, & McPherron, 2016). Latent utilitarian ape behaviours are strong candidates for latent utilitarian behaviours in all hominins (ibid.; see also Reindl, Beck, Apperly, & Tennie, 2016; Tennie, 2023; Tennie, Premo, Braun, & McPherron, 2017). But our main point here is that such latent behavioural capabilities exist outside the utilitarian domain, too, and it is especially these abilities that can give rise to outcomes that become instances of false-symbol interpretations.

Given primates' close phylogenetic proximity to humans, "primate art" is a prime example of how this issue may play out. Here, we are uninterested in the monetary or aesthetic value which humans attach to such items (which may be considerable). Nor are we interested in attempting to define "art." Instead, we simply note that there are things primates make which humans routinely label "art," and we note that art is generally linked to symbolic cognition by archaeologists (Stibbard-Hawkes included). What significance do these items have for the symbolic interpretation of similar items found in the archaeological record (regardless of their specific medium)?

A good start on this question can be made through a careful re-analysis of the extant literature on primate art (a task we are currently undertaking). Such a re-analysis must filter evidence in three ways. First, some of the primates involved were human enculturated. As is widely acknowledged, such enculturation can push primate minds and/or behaviour generally in the direction of the human range (e.g., Kanzi the bonobo). Second, some of the primates were trained to perform various "artmaking" tasks. Third, some had artmaking demonstrated for them by humans (e.g., how, where, when, etc., to make art). Strictly speaking, only cases involving *unenculturated*, *untrained*, and *demonstration-naïve* primates (or other animals, e.g., elephants) are relevant. The simple reason is that humans did not (and we suspect, will not) use time-machines to "go back" and enculturate, train, or demonstrate art for their Pleistocene relatives.

Sadly, the vast majority of cases of primate art prove irrelevant by these three standards. We plan to conduct work soon that avoids these confounds. But for now, a single proof-of-principle case is enough to show our approach holds water. Fortunately, there would appear to be at least one such case: In the 1990s, Westergaard and Suomi (1997) provided capuchin monkeys with clay, paint, and various other materials (sticks, stones, etc.). These monkeys were unenculturated, untrained (personal communication), and the paper mentions no human modelling. These *relevant* monkeys nevertheless spontaneously made non-utilitarian marks – in a variety of ways – including with paint, and including parallel scratch and even chisel marks. By "non-utilitarian," we here mean that the marks were made for no apparent practical purpose, *nor* as a by-product of some activity done for a practical purpose, for example, cutting food. An onlooker may well have concluded the capuchins were making art, and that they were creating "symbolic material culture." However, most would deny that (untrained, unenculturated, naïve) capuchins produce and use symbols in any interesting sense. Yet, such capuchins clearly produce outcomes (markings) on par with outcomes that many archaeologists treat as symptomatic or at least suggestive of symbolic cognition and culture. Were we to discover principally similar markings (e.g., non-iconic etchings on a cave wall) known to be made by hominins, they would likely be interpreted as symbolic (see, e.g., Fuentes et al., 2023 on potential *Homo naledi* engravings).

The main point is this: The presence of non-utilitarian markings made by hominins at an archaeological site is therefore not in itself a safe means of inferring the presence of human-like symbolic cognition (or human-like culture). To show a symbolic origin, more data are needed. The simple reason is that at least some primates are apt to spontaneously produce such outcomes, despite (likely) lacking symbolic capacities in anything like the sense archaeologists seem interested in when they speak of "symbolism." Thus, in addition to false negatives, archaeology faces a false-positive problem in regard to symbol identification. Although the symbolic status of (e.g.) representational cave art cannot be seriously doubted, that is not true in every case of, say, engraved zigzag designs, parallel lines, or finger flutings.

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Perishable material choice indicates symbolic and representational capacities

Elpida Tzafestas*

Department of History and Philosophy of Science, National and Kapodistrian University of Athens, University Campus, Ano Ilisia, Athens, Greece
etzafestas@phs.uoa.gr; http://scholar.uoa.gr/etzafestas/

*Corresponding author.

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Abstract

The absence of symbolic material cultural objects in the archaeological record does not prove absence of symbolic cognition. Sometimes perishable materials are selected for symbolic roles, for practical concerns or to indicate a temporary condition. Also some symbolic functions may predate the use of durable materials. Finally, child play and artisan experimentations usually involve cheap and perishable materials. These are symbolic and representational activities that do not leave a material trace.

The absence of symbolic material cultural objects in the archaeological record is commonly used as an indication of absence of symbolic cognition. As Stibbard-Hawkes convincingly argues, based on the data on modern hunter-gatherers, material culture of symbolic value may be made by perishable materials (e.g., skin) and thus may not be retrievable in the archaeological record. This is an indication that the common reasoning about the origins of symbolic cognition in our species' past is partly flawed.

But is the use of perishable materials common and to what degree can it be a choice? Firstly, there are practical reasons for choice of any material, most notably functionality and availability, as the author puts forth. One should not overlook the fact that a material that functions well and is available will most probably be immediately chosen for use. Later innovations may account for replacement by a more durable material, when the technology to shape it at will becomes available and this is also a matter of the more general context. For example, our idea of the origin of a helmet relates to the ancient Greek and Roman metal helmets (made by bronze or iron), but these helmets have evolved from older versions made by leather or wood (e.g., Coutil, 1915). These helmets have strikingly similar forms as the helmets used for sun protection in Hawaii and Polynesia that are made mostly by fiber or rope (e.g., the Hawaiian "mahiole," Buck, 1957). Still, no matter the material of the helmet's body in Europe or in the Pacific, they all carry many ornamental features made of perishable materials, such as horse hair crests of Roman galeae or feather ridges of mahioles. These additional features have a specific symbolic value, related to rank, genealogy, achievements, and so on. Even today, military insignia, noble family emblems, and various symbolic flags are made by perishable materials, most typically cloth. So, we have good reasons to think that very often the symbolic value and function predates the eventual use of durable materials.

There is an additional explanation why objects of symbolic value might be perishable: That the use of material of perishable nature may not only be a matter of availability, but also a deliberate choice made by a population. There are at least two reasons one might imagine. Firstly, objects of obvious functional value, such as cooking pots, tools, and so on, are prone to be crafted and selected for functionality, and are thus prone to wider use of non-perishable, harder, and heavier materials that enhance functionality, despite their disadvantage when being carrying around. This is not true for objects of symbolic value: For example, ornaments made by perishable materials are typically lighter and easier to carry during migrations, thus they will be preferable for this same reason. On the other hand, and more importantly, ornaments and jewels made by perishable materials need frequent replacement, and this may represent a sign of continuous well-being and care or a sign of, precisely, a temporary state. For example, flower necklaces are very common in India during feasts and celebrations (Thakur, 2018) and the laurel leaf wreaths were a sign of victory in the ancient Olympic games (Kefalidou, 2009). None of these leaves material traces. There is no reason to believe that such practices were absent in human populations of the distant past. The tendency to hoard and preserve is a trademark of more recent, sedentary populations and may also be a cultural element that unconsciously biases our understanding of what is a normal "modern" behavior and our interpretation of the past.

Finally, there are also more broadly cognitive, and not necessarily linguistic, manifestations of the representational and symbolic species that we are (Deacon, 1998), through activities that rely on the choice of preferably perishable materials and these generally are also found in our human society today. Two prominent such activities are play and artisanry. Children at play use materials that have two properties: Availability and malleability. Cloth, wax, pieces of wood and rope, plant leaves and other parts, clay, and so on, together with natural objects, such as little stones and shells, have been preferred such materials by children of all times and places until fabricated toys became commercially available and overtook the toy landscape. For example, figurines or pretend objects have always been common toys and these are shaped by children that are in the process of development and understanding of the world around them. This is especially obvious in the middle stages of cognitive child development before adolescence (informal operational stages from 2 to about 11 years old, according to Piaget, 1962). The children of these ages engage consistently in constructive and symbolic/fantasy play where they adopt roles and perform make-believe tasks with pretend objects that represent real-world counterparts, or practice and learn new skills, explore interests and relationships, and so on. Because the children's play is spontaneous and only a little organized, imagination plays an important role and the children's attention often shifts, so that the use of easily available and malleable materials is preferred. This is why parents of children of these ages are encouraged to provide rich environments to their children to boost their imagination and their development. Most of these would not leave any trace in the archaeological

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record. Very similar conditions apply to artisanry. Many technological advancements are not outcomes of sudden inspiration but result from persistent experimentation that resembles children's play except that it pursues functional goals. Artisans use soft molds, scales, arbitrary cheap and available objects, and so on. An artisan may experiment with a new type of paddle by binding together a couple of twigs with a piece of rope. Again, all these activities are of symbolic and representational value, no different than what humans of our time are doing, and yet they leave no trace.

As a consequence, all the examples and the arguments exposed before provide additional support in favor of the author's view, although they make inferences about cognitive evolution more speculative.

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Shared intentionality may have been favored by persistence hunting in *Homo erectus*

Jared Vasil*

Department of Psychology and Neuroscience, Duke University, Durham, NC, USA
jared.vasil@duke.edu

*Corresponding author.

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Abstract

Shared intentionality is the derived hominin motivation and skills to align mental states. Research on the role of interdependence in the phylogeny of shared intentionality has only considered the archeological record of *Homo heidelbergensis*. But ethnographic and fossil data must be considered, too. Doing so suggests that shared intentionality may have been favored in *Homo erectus* to support persistence hunting.

The target article necessitates reconsideration of the "ancestral null" hypothesis. This hypothesis states that "without positive [archaeological] evidence to the contrary, past humans should not be considered cognitively or behaviorally sophisticated" (target article, Sect. 4, para. 6). The ancestral null is tacitly accepted by the interdependence hypothesis (Tomasello, Melis, Tennie, Wyman, & Herrmann, 2012). Consequently, that hypothesis suggests an unnecessarily vague and temporally inaccurate phylogeny of shared intentionality. An alternative links psychological with ethnographic and fossil data to suggest that shared intentionality may have been favored by persistence hunting in *H. erectus*.

The interdependence hypothesis describes the phylogeny of shared intentionality. Shared intentionality is the motivation and skills to align mental states. Arguably, shared intentionality underlies humans' derived communicative and cooperative behavior (Tomasello, 2019). The evolutionary model is the stag hunt (Skyrms, 2004). In stag hunts, cooperation maximizes individual payoff. Thus, partners have a stake in ensuring that both cooperate adequately (Roberts, 2005). However, partners are fallible, and their intentions are uncertain. Thus, cooperation is risky. Sharing intentions by communicating reduces uncertainty and, therefore, risk. Consequently, cooperators can outcompete noncooperators by sharing intentions with likeminded partners.

As an evolutionary narrative of shared intentionality, the above has two shortcomings. First, there is unnecessary vagueness about the form of stag hunts. It is "unnecessary" because some evidentiary sources, like ethnographies and fossils, are neglected. Tomasello, Hare, Lehmann, and Call (2007) demonstrate the cooperative function of white sclera, but sclera do not fossilize. Instead, Tomasello et al. (2012) only consider archaeological evidence for interdependent hunting. Moreover, all hypothetical examples include only material culture (e.g., spears). This suggests acceptance of the ancestral null, which invites inaccurate phylogenetic timelines. Indeed, this is the second problem. Tomasello et al. (2012) suggest that interdependent foraging first occurred in *H. heidelbergensis* (also, Tomasello, 2014, 2019, 2022). This understates the antiquity of shared intentionality.

Rather, shared intentionality may have been favored by persistence hunting in *H. erectus*. Persistence hunters use endurance running to chase prey to exhaustion (Carrier, 1984). Exhausted prey can be safely killed with simple weapons, for example, rocks. Persistence hunting by *H. erectus* explains its cursorial adaptations (Bramble & Lieberman, 2004), patterns of meat acquisition, and encephalization (reviewed in Pontzer, 2017). In short, if (i) contemporary persistence hunting is an interdependent, energetically profitable subsistence strategy and (ii) fossil evidence does not preclude persistence hunting by *H. erectus* (i.e., insofar as cursorial traits are attested), then shared intentionality may have been favored by persistence hunting in *H. erectus*.

Is there evidence for (i)? Ethnographies portray persistence hunting as interdependent and profitable. Lieberman et al. (2020) argue that effective persistence hunting requires cooperation. Those authors discuss Rarámuri individuals' recollections of persistence hunting. All persistence hunts were performed by groups. Sometimes, groups drove prey into traps while others ran alongside to prevent its escape, or else groups chased prey to exhaustion and killed it with rocks. Aboriginal peoples have reportedly jointly pursued kangaroos (Tindale, 1974). One individual chases while the other intercepts the kangaroo's path, reversing roles until the kangaroo becomes exhausted. Liebenberg (2006) discusses !Xo and /Gwi hunters (central Kalahari, Botswana) alternating tracker or chaser roles in persistence hunts. All three citations suggest the importance of (joint commitment to) shared goals and individual roles for persistence hunting. Moreover, tracking is often collaborative. Liebenberg (1990) discusses how "tracks are commented on by… gesture

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[and] soft whispers" so as not to spook prey (p. 55). He argues that "success… depends on how quickly the animal can be tracked down" (Liebenberg, 1990, p. 61). This implies ecological pressure for derived communicative skills and motivations, like shared knowledge ("What do we both know and what do only I know?"), the motivation to increase shared knowledge (e.g., via linguistic reference; Vasil, 2023), and false belief and joint reasoning ("Why should we follow which tracks?"). The metabolic expense of using the body as a foraging tool – compared to, say, shopping carts or guns – probably contributes to the rarity of persistence hunting, today (Lieberman, Bramble, Raichlen, & Shea, 2007). However, persistence hunting can kill prey large enough to require cooperation to transport and consume (for prey sizes, see Morin & Winterhalder, 2024). Consequently, persistence hunting is likely to be profitable, on average (Morin & Winterhalder, 2024). Altogether, this supports (i) that contemporary persistence hunting is interdependent and energetically profitable.

Is there evidence for (ii)? *H. erectus* possessed derived cursorial traits, like a plantar medial longitudinal arch (reviewed in Holowka & Lieberman, 2018). The arch is maintained by bony and soft tissue structures (Huang, Kitaoka, An, & Chao, 1993). The vertical loads of running compress bony structures, and compression stretches soft structures, like the plantar aponeurosis (Ker, Bennett, Bibby, Kester, & Alexander, 1987). The stretched plantar aponeurosis stores elastic strain energy. Releasing this energy at push-off propels runners forward, like hopping on springs (Holowka, Richards, Sibson, & Lieberman, 2021). This increases locomotor efficiency because elastic strain is generated passively (Alexander, 1991). Importantly, the arch's spring is likely a cursorial adaptation, and not a spandrel associated with bipedal walking. Walking compresses the arch (Caravaggi, Pataky, Günther, Savage, & Crompton, 2010). However, only running causes compression sufficient to engage the spring mechanism (Stearne et al., 2016). Moreover, similarities in the walking kinematics of humans and nonhuman apes (who lack the arch) suggest that the arch is not required for hominin stiff-lever walking (Holowka & Lieberman, 2018); and the transverse arch greatly stiffens the foot during walking and predated *Homo* (Venkadesan et al., 2020). Thus, evidence of a longitudinal arch in *H. erectus* suggests cursorial adaptedness. Perhaps the arch supported persistence hunting by cooperative *H. erectus* groups (Hatala et al., 2016). Altogether, this supports (ii) that fossil evidence does not preclude persistence hunting by *H. erectus*.

In conclusion, shared intentionality may have been favored by persistence hunting in *H. erectus*. This "first step" in the evolution of shared intentionality enabled its "second step" (Tomasello et al., 2012), partially preserved in the archeological record as evidence of "mosaic cumulative culture" and "technological ratchets" (target article, Sect. 13, para. 4). This discussion excluded necessary questions of life history. Perhaps shared intentionality was also favored by alloparenting in *H. erectus* (O'Connell, Hawkes, & Blurton Jones, 1999; see Hrdy, 2009; relatedly, Lieberman, Kistner, Richard, Lee, & Baggish, 2021).

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Animal artefacts challenge archaeological standards for tracing human symbolic cognition

Jan Verpooten[a,b]* and Alexis De Tiège[c]

[a]Behavioural Engineering Research Group, KU Leuven, Leuven, Belgium; [b]Behavioural Ecology and Ecophysiology, University of Antwerp, Antwerp, Belgium and [c]Centre for Logic and Philosophy of Science, Ghent University, Ghent, Belgium
Jan.verpooten@kuleuven.be
Alexis.DeTiege@UGent.be
https://www.janverpooten.com/

*Corresponding author.

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Abstract

Stibbard-Hawkes challenges the link between symbolic material evidence and behavioural modernity. Extending this to non-human species, we find that personal adornment, decoration, figurative art, and musical instruments may not uniquely distinguish human cognition. These common criteria may ineffectively distinguish symbolic from non-symbolic cognition or symbolic cognition is not uniquely human. It highlights the need for broader comparative perspectives.

Stibbard-Hawkes' comparative research challenges the assumed link between symbolic material evidence and behavioural modernity. We extend this approach to non-human species, focusing on common evidentiary criteria for human symbolic cognition (reviewed in Stibbard-Hawkes; see also Table 1 in the target article): Personal adornment, decoration, figurative art, and musical instruments. Our examination suggests that these standards might not effectively distinguish human from non-human animal behaviours, because they do not differentiate symbolic from non-symbolic cognition or because symbolic cognition is not uniquely human. This highlights the need for broader comparative perspectives.

Ochre use, an example of personal adornment interpreted as symbolic evidence in humans (e.g., d'Errico & Henshilwood, 2011), is paralleled by birds' "cosmetic coloration" (Delhey, Peters, & Kempenaers, 2007). Bearded vultures, for example, apply ochre to their bodies for status signalling, not utilitarian uses (Duchateau, Chéliz, Gil, & López-López, 2022). Given their shared environments and practices, and since vulture evolution predates humans, it is possible that hominins copied this behaviour from these birds (Margalida, Almirall, & Negro, 2023).

Non-utilitarian decorative objects or decorations of utilitarian artefacts are seen as symbolic as well (e.g., d'Errico & Henshilwood, 2011). However, non-mammalian animals like spiders, insects, crustaceans, birds, and fish commonly use artefactual decoration for communication (Schaedelin & Taborsky, 2009). For example, male bowerbirds construct utilitarian objects (i.e., protective bowers) and decorate them with a diverse but selective collection of non-utilitarian objects, similar to ancestral hominin manuports. They also paint walls with processed vegetal residues (Hicks, Larned, & Borgia, 2013), and even create theatres with forced perspective illusions, a technique humans only invented in the Renaissance (Endler, Endler, & Doerr, 2010).

Figurative art like figurines and representational rock art is considered a stringent and "unquestionable" criterion of uniquely human symbolic cognition, emerging as recently as 40–50 ka (Klein, 2017, p. 213). However, as many animal species intentionally create resemblances to biotic and abiotic elements, non-human artefacts can also meet this criterion. For instance, wild orangutans create and cuddle "dolls" made of leaves (Bastian, Van Noordwijk, & Van Schaik, 2012; Laland, 2017; Van Schaik, Van Noordwijk, & Wich, 2006), and a captive dolphin calf imitated cigarette smoke with milk (Patterson & Mann, 2015). Vocal imitation, an acoustic equivalent of figurative art, is

Table 1 A non-comprehensive overview of proposed artefactual criteria (column 2) evidencing aspects of complex behaviour and cognition (column 1) adopted from Table 1 in Stibbard-Hawkes. Non-human animal evidence meeting these criteria (column 3) suggests that these archaeological standards may not accurately track uniquely human behavioural modernity and cognition, underscoring the need for broader comparative perspectives

Behaviour/capacity	Proposed artefactual evidence	Non-human animal evidence	References
Ritual behaviour	Pigment use	Cosmetic colouration (e.g., vulture ochre use for status signalling)	Delhey et al. (2007); Duchateau et al. (2022)
Behavioural modernity	Colourants		
Symbolic behaviour	Decoration	Artefactual decoration in diverse taxa (including transport and compound paint use in bowerbirds)	Endler et al. (2010); Hicks et al. (2013); Schaedelin and Taborsky (2009)
Language; symbolic behaviour; complex communication systems	Personal ornament		
Advanced planning	Material transport		
Complex cognition	Compound paints		
Language; symbolic behaviour; working memory; cognitive fluidity and creative thought; behavioural modernity	Figurative art (i.e., artefacts created to resemble elements of the physical world)	Intentional creation of visual (e.g., orangutan "leave dolls" and dolphin "milk smoke") and acoustic semblances (e.g., individual imitative labelling in dolphins and parrots, and a mixed species mobbing flock illusion in lyrebird)	Dalziell et al. (2021); King and Janik (2013); Laland (2017); Patterson and Mann (2015); Scarl and Bradbury (2009)
Language; systemizing thoughts; behavioural modernity	Musical instruments	Non-bodily acoustic communication in diverse taxa, including homologous drumming (with stones) on trees in great apes; cockatoo drumming on hollow trees with modified stick	Dufour et al. (2015); Eleuteri et al. (2022); Fitch (2015); Heinsohn et al. (2017); Kühl et al. (2016)
Advanced planning; complex cognition; behavioural modernity	Composite tools		

prevalent in cetaceans, pinnipeds, elephants, bats, songbirds, hummingbirds, and parrots (Verpooten, 2021). This sophisticated cognition is an essential prerequisite for (spoken) language and is thus at least as relevant to symbolic cognition as figurative art (Jarvis, 2019; Tyack, 2020). It is used by elephants, dolphins, and parrots to label and address individuals (King & Janik, 2013; Pardo et al., 2024; Scarl & Bradbury, 2009), and by lyrebirds to create a complex acoustic illusion of a mixed species mobbing flock (Dalziell, Maisey, Magrath, & Welbergen, 2021). Unlike non-human primates, thousands of species exhibit vocal imitation, emphasizing the need for a broader comparative perspective in studying the evolution of symbolic cognition (Fitch, 2015; Tyack, 2020; Verpooten, 2021).

If defined as non-bodily objects for acoustic communication, musical instruments are also not uniquely human. Many primates use objects for acoustic displays, such as branch shaking. Orangutans modify vocal displays using leaves. Percussive drumming in African great apes likely evolved in our common ancestor (Fitch, 2015). Chimpanzees drum on tree roots, producing signals similar to human drumming (Dufour, Poulin, Curé, & Sterck, 2015; Eleuteri et al., 2022) and amplify drumming with stones, creating rock accumulations akin to human cairns (Kühl et al., 2016).

Beyond primates, other mammals and birds, like woodpeckers, use non-bodily means for structured communicative sounds (Fitch, 2015). Narrowing the definition to manufactured instruments, male palm cockatoos use modified sticks or seedpods to drum on hollow trees during courtship displays, sharing key features with human instrumental music like rhythm and individual styles (Heinsohn, Zdenek, Cunningham, Endler, & Langmore, 2017). This behaviour also exemplifies composite tool manufacture, a marker of cognitive complexity (Stibbard-Hawkes).

Extending Stibbard-Hawkes' critique, this artefactual evidence from diverse animals suggests that archaeological standards for human cognitive modernity may not exclude animal behaviours. Table 1 summarizes non-human evidence and the corresponding archaeological criteria. A broader comparative approach may clarify why this seems to be the case. One possibility is that these criteria ineffectively distinguish symbolic from non-symbolic cognition. Sophisticated artefacts may not need sophisticated cognition (reviewed in Stibbard-Hawkes). Figurative art, for example, could be accounted for by mere sensory manipulation, a common aspect of animal signalling dynamics (De Tiège, Verpooten, & Braeckman, 2021; Verpooten & Nelissen, 2010).

Alternatively, these evidentiary standards might indicate symbolic cognition, but the assumption that this is a uniquely human trait, let alone a tell-tale sign of human behavioural modernity, could be incorrect. Linguists often view recursion as a fundamental characteristic of language. When two syntactic objects are combined or "merged" to form a new syntactic unit, recursion implies that this merging can be applied to its own output, allowing for displaced reference (i.e., detachment from the immediate context), a hallmark of full symbolism (Planer, 2021). Most non-human animal signals are "0-merge" systems without syntactic recombination (Suzuki & Zuberbühler, 2019). However, some animals exhibit "1-merge" systems with basic compositional syntax (Suzuki, Wheatcroft, & Griesser, 2020). For instance, Japanese tits combine alert and recruitment calls into sequences for mobbing predators. Some animal communication systems, like cetaceans, may involve human-level "2-merge" and "3-merge" systems with recursive units, allowing for displaced reference and full symbolism (Allen, Garland, Dunlop, & Noad, 2019; Andreas et al., 2021; Cannon, 2023). Although animal symbolic cognition is not definitively demonstrated, research is progressing (Pepperberg, 2017), aided by AI-assisted decoding of patterns in animal signalling (Andreas et al., 2021; Pardo et al., 2024).

In conclusion, the wide range of artefactual and communicative behaviours in different species challenges conventional criteria for uniquely human attributes and questions their absence in archaeological discourse. Our exploration advocates for a broader comparative approach in studying human cognitive origins, emphasizing its importance in identifying reliable archaeological indicators of uniquely human "modern" behaviour and symbolic cognition. For instance, the absence of vocal imitation ability, required for spoken language, in non-human primates and its presence in more distantly related taxa like cetaceans and parrots highlights this need. This discourse aims to open new pathways for understanding the evolution of human cognition and behaviour.

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Archaeology retains a central role for studying the behavioral and cognitive evolution of our species and genus

Manuel Will[a,b]*

[a]Department of Early Prehistory and Quaternary Ecology, University of Tübingen, Tübingen, Germany and [b]Palaeo-Research Institute, University of Johannesburg, Auckland Park, South Africa
manuel.will@uni-tuebingen.de
https://uni-tuebingen.de/fakultaeten/mathematisch-naturwissenschaftliche-fakultaet/fachbereiche/geowissenschaften/arbeitsgruppen/urgeschichte-naturwissenschaftliche-archaeologie/ina/aeltere-urgeschichte-quartaeroekologie/mitarbeiter/professoren-privatdozentinnen-und-privatdozenten/priv-doz-dr-manuel-will/

*Corresponding author.

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Abstract

Our species' behavioral and cognitive evolution constitute a key research topic across many scientific disciplines. Based on ethnographic hunter-gatherer data, Stibbard-Hawkes challenges the common link made between past material culture and cognitive capacities. Despite this adequate criticism, archaeology must retain a central role for studying these issues due to its unique access to relevant empirical evidence in deep time.

The origins of the cognition, behavior, and culture that characterize our species have preoccupied diverse fields such as philosophy, history, and biology for a long time. With the rise of Paleolithic archaeology and Paleoanthropology in the 19th and 20th century, questions on what makes us human and how and when this happened coalesced into a disciplinary agenda grounded in empirical data from deep time. Today we know that our biological origins stretch back to between 300,000 and 200,000 years ago in Africa (Hublin et al., 2017; Vidal et al., 2022). Models on the mode, tempo, and places for the behavioral and cognitive evolution of *Homo sapiens* in archaeology have changed markedly and remain contested: From an Upper Paleolithic revolution in Europe (Mellars & Stringer, 1989) to an earlier and gradual accumulation in Africa (McBrearty & Brooks, 2000) or a mosaic evolution on this continent (Scerri & Will, 2023) and beyond (Conard, 2015). One central conviction has remained unchanged, however: The pivotal role of past material culture to understand these processes.

The thought-provoking article by Stibbard-Hawkes provides a different angle on this issue from the ethnography of contemporary hunter-gatherers, questioning the validity of links between cognitive capacities and material culture. The critical assessment of his findings regarding the use of archaeological materials to trace cognitive traits or mental revolutions in the deep past is a welcome addition to all relevant fields. The article rightly puts its finger on the weak spots of archaeological data – taphonomy, underdetermination, equifinality, absence of evidence – and overtly cognitive interpretations. While potentially off-putting for some archaeologists, I view the contribution as a wake-up call and constructive challenge; a welcome reminder to check our interpretations and biases. Too often have scholars drawn straightforward connections between material culture and specific measures of cognitive capacities or behavioral complexity – me included. The article showcases the value of ethnographic data for framing our inferences and considering multiple, alternative interpretations which can guide the study of Pleistocene humans closer along relevant and testable hypotheses.

What I want to assess more closely are the ramifications of this work for archaeology that could be seen as paralyzing and incentive to abandon this research direction altogether. Yet, we don't need less archaeological study of our behavioral and cognitive evolution but more, set in a wider temporal and taxonomic framework. The archaeological record in the form of artifacts and other material traces remains the principle empirical source for inferences on behavior, culture, and cognition in the past, spanning many hundreds of thousands of years and different species of *Homo*. It is less fragmentary compared to the paleoanthropological record that provides complementary information on the related evolution of our brains and bodies in the Pleistocene.

While biological evolution continued since the origin of our species (e.g., Harvati & Reyes-Centeno, 2022; Mirazón Lahr, 2016), culture and behavior undergo the most dramatic changes with lasting influences on our cognition via increasing material engagement and bio-cultural feedback (Hussain & Will, 2021; Laland, Odling-Smee, & Myles, 2010; Malafouris, 2013). Even more reason to study the diverse and vast Pleistocene archaeological record of our species and other hominins.

To unravel long-term, evolutionary processes, of which our brains, behavior, and culture are part, we require relevant diachronic data, the more the better. It is not just "standard archaeology" in the forms of excavating, collecting, and analyzing objects of the past but also "squeezing blood from stones" (Isaac, 1977) and other materials by employing the full battery of approaches from zoology, material sciences, botany, paleogenetics, proteomics, and so on. In a second step, taking up Stibbard-Hawkes criticisms and following the method of multiple working hypotheses (see Chamberlin, 1890), the resulting multidisciplinary patterns on our past require a more careful construction of bridging theories and testing potential connections to cognition against other domains such as functional, cultural, ecological, or demographic variables both within but also across species of *Homo*. Predecessors on which such future work can build already exist (e.g., Coolidge, Haidle, Lombard, & Wynn, 2016; Haidle, 2014). Changing our basic assumptions on what the absence of specific material traces means may also help, as Stibbard-Hawkes points out. Here I find Haidle's (2016) distinction between performances and capacities most helpful: Reflections of behavioral performances are empirically traceable, whereas present cognitive capacities might remain unexpressed and archaeologically invisible. This resonates to a large degree with the presented findings on recent hunter-gatherers.

For practitioners in the field, much of the above may seem trivial. Considering the large and diverse readership of this journal, however, it requires reiteration that archaeology retains a central role to study the behavioral and cognitive evolution of *Homo sapiens* and their relatives with its unique diachronic and interspecies framework throughout ~3 million years. Too often, perspectives from outside the field with passing knowledge of the complex and unwieldy archaeological record have provided distorted portrays of human origins that gained considerable traction, also with the public (e.g., Harari, 2014). Furthermore, arguing mostly from the present human brain, its psychology or specific cultural patterns downplay and undervalue the long, contingent evolutionary pathways that led us to where we are now. To arrive at a holistic picture, we need evidence from the past and present, combining "neontological" and "paleontological" approaches.

Stibbard-Hawkes flags the many challenges that await such a massive endeavor, and this "just" from the perspective of hunter-gatherer ethnography. I don't have a simple answer to all the issues posed by this important contribution, and I assume many archaeological readers may have a similar uneasy feeling, particularly where absence of evidence is concerned. The wrong reaction would be to lay down our arms and look towards other fields that will resume study in these directions. As a starting point, archaeologists should continue cultivating an open, critical, and multidisciplinary mindset to pursue research into the behavioral and cognitive evolution of our species in a multi-species, diachronic framework of multiple, testable working hypotheses. Promoting genuine collaboration with other relevant fields will also ensure that empirical data of the deep past assumes its privileged role in the study of human origins in science and the public.

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Author's Response

Hominin cognition: The null hypothesis

Duncan N. E. Stibbard-Hawkes*

Department of Anthropology, Durham University, Durham, UK
duncan.stibbard-hawkes@durham.ac.uk

*Corresponding author.

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Abstract

The target article explores material culture datasets from three African forager groups. After demonstrating that these modern, contemporary human populations would leave scant evidence of symbolic behaviour or material complexity, it cautioned against using material culture as a barometer for human cognition in the deep past. Twenty-one commentaries broadly support or expand these conclusions. A minority offer targeted demurrals, highlighting (1) the soundness of reasoning from absence; and questioning (2) the "cognitively modern" null; (3) the role of hunter-gatherer ethnography; and (4) the pertinence of the inferential issues identified in the target article. In synthesising these discussions, this reply addresses all four points of demurral in turn, and concludes that there is much to be gained from shifting our null assumptions and reconsidering the probabilistic inferential links between past material culture and cognition.

R1. Introduction

If one delved too deeply into the idea of latent cognitive potential, not expressed in the archaeological evidence, hypotheses concerning stages and tempo of evolution of behavior and culture would stand on shaky ground.

– Hovers and Belfer-Cohen (2006, p. 296)

It is an error to equate the documented history of intellectual achievement with a history of intellect.

– Blurton Jones and Konner (1989, p. 348)

Researchers from across the behavioural and brain sciences have linked past artefactual remains to the trajectory of human cognitive evolution. The target article reconsidered this link from the perspective of hunter-gatherer ethnography, exploring the material culture of three African hunter-gatherers. By investigating material use, particularly in the production of "symbolic" and non-utilitarian artefacts, it demonstrates that one of three populations would leave scant discernible evidence of material complexity and, except for occasional ostrich eggshell beadwork, neither would the others. It explored the relationship between artefact function and preservation probability, showing that utilitarian tools used in manufacture, cooking and material processing are more likely to contain enduring materials than other artefacts. It also explored differences in material selection between populations, revealing that pragmatic concerns – for example, material availability, mobility, cultural transmission – are primary in shaping the material record of contemporary and probably past humans, independent of cognitive capacity difference.

The 21 commentaries largely endorse the target article's thesis: That contemporary humans need not leave enduring evidence of symbolic behaviour nor, probably, broader technological sophistication – so we should be hesitant when reasoning from its absence. Most commentaries offer fertile extensions to the discussion, exploring (1) the relevance of findings to other cognitive sciences (i.e., linguistics; **Kuleshova, Pleyer, Blomberg, Sibierska, & Wacewicz** [**Kuleshova et al.**]), and other categories of artefactual evidence (i.e., weaponry; **Milks**); (2) the parallel risk of over-interpreting extant symbolic evidence (**Verpooten & De Tiège**; **Tennie & Planer**); (3) the importance of considering perishable artefacts in reconstructions of past (Palaeolithic and Pliocene) behaviour (**Falk**; **Gallup & Eldakar**; **Vasil**; **Tzafestas**); (4) the role of materiality and other cultural process in shaping our cognitive worlds (**Di Paolo, White, Guénin–Carlut, Constant, & Clark** [**Di Paolo et al.**]; **Will**; **Ben-Oren, Hovers, Kolodny, & Creanza** [**Ben-Oren et al.**]); (5) the difficulties of the behavioural modernity concept (**Blessing**; **Blurton Jones**); (6) new models for measuring material complexity (**Grüning & Grüning**); (7) the continuing importance of cognitive archaeology (Will); and (8) the possibility that humans need not engage in any symbolic activities at all (Ben-Oren et al.).

A minority of commentaries offer demurrals along four lines, highlighting (1) the situational soundness of reasoning from absence (**Sterelny**; **Irurtzun**; **Liu & Stout**); and questioning (2) the wisdom of adopting a "cognitively modern" null model (**Bedetti & Allen**; Irurtzun); (3) the relevance of hunter-gatherer ethnography to the past (**Protzko**); (4) the pertinence or soundness of the inferential problems identified in the target article (Liu & Stout; **Sergiou & Gabora**; **Barceló-Coblijn**).

Here I synthesise these commentaries, with particular focus on demurrals. I explore the criteria artefacts must meet to draw inferences from their absence. I justify and develop the "derived"/"cognitively modern" null model, clarifying that this is not a conjecture but a heuristic. I explore the role of hunter-gatherer research in reasoning about the past. Last, I address concerns that the target article misrepresents (i.e., "straw-mans") scholarly consensus, and argue that there is still cause to reconsider the link between past artefacts and past minds.

R2. Inferences from absence: The devil is in the details

After exploring perishable material-use among three contemporary African foragers, the target article cautions against using absent evidence of complex technology, or absence-to-presence transitions, to infer shifting capacity. In response, four commentaries (**Sterelny**; **Irurtzun**; **Kuleshova et al.**; **Liu & Stout**; **Sergiou & Gabora**) rightly highlight that negative evidence (Wallach, 2019) can be "epistemically sound and scientifically strategic." Situationally, this is straightforwardly true. Indeed, it is personally relevant: As I type, I have been grazing on a bag of imported French chocolates. In my distraction, I find the bag empty. My partner, currently out, has near-complete knowledge of the processes by which the snack cabinet is emptied, and the absence of the chocolates on her return will, unfortunately, provide inviolable proof of the culprit (me).

In this example, absent evidence provides near-definitive support for a hypothesis. However, as **Irurtzun** highlights, even where absence provides weaker probabilistic evidence, it may still shift beliefs. Like many commenters (**Liu & Stout**; **Will**; Irurtzun; **Sergiou & Gabora**), I strongly endorse a probabilistic framework (see Killin & Pain, 2021; Wallach, 2019), incorporating multiple categories of evidence for reasoning about the unknown. Often the absence of certain material remains can indeed probabilistically update our beliefs about past behaviour. For example, animal husbandry practiced at large scale produces an enduring signature of faunal remains, and so the absence of any middle-Pleistocene signature is informative. By integrating other lines of evidence, for example, contemporary and ancient genomic data (Frantz, Bradley, Larson, & Orlando, 2020), climatic data (Ho et al., 2008), or, for dairy animals, the patterning of human lactase persistence (Campbell & Ranciaro, 2021; Leonardi, Gerbault, Thomas, & Burger, 2012), we may build credible probabilistic models of the chronologies of livestock domestication (Zheng et al., 2020).

Sterelny gives another example, highlighting the lack of evidence for hafting (attaching a tool-head to a handle, e.g., in

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axe-, knife- or arrow-making) among *Homo heidelbergensis* and contemporaries (though see Wilkins, Schoville, Brown, & Chazan, 2012). Sterelny suggests "this is good evidence that, minimally, hafted tools were not regularly part of these hominins" technical repertoire and, more strongly, that they lacked the capacity to haft tools."

To reason from absence like this, **Irurtzun** reminds us, "the devil is in the details," which must be precisely formulated. Here, at least two conditions must be met. First, the artefact in question must probabilistically entail use of enduring media in sufficient quantities to produce a signature. Second, the "capacity" for making it must be reliably linked to the probability of making it. I discuss these two conditions in turn.

R2.1. Condition 1: Probabilistic use of enduring media

The first requirement for reasoning from absence here is the probabilistic use of enduring materials. As discussed in section 10.2 of the target article, many artefacts which may contain enduring media need not do so. However, in **Sterelny**'s hafting example, this condition is well satisfied: Hafted tools are typically weapons, or tools of manufacture/butchery which, by dint of their function, often incorporate hard, enduring media (target article, sect. 12). Thus, if hafted tool-heads were produced at scale, they should appear in any well-sampled assemblage (as perhaps they do, see Wilkins et al., 2012) and their absence is informative. Modified ochre is another enduring material, so should also be archaeologically visible were it widely used. As **Ben-Oren et al.** highlight, its patchiness throughout the human record may indicate only situational importance. Here, again, negative evidence proves informative.

Note though, that this condition is met only for a small subset of total material repertoires even among contemporary African foragers. The data presented in the target article show that, excluding traded media, an estimated 92% of Mbuti, 83% of Hadza, and 76% of G//ana artefactual repertoires contained *no enduring materials*. Focusing only on that minority of artefacts where absence is informative may seriously blinker us to the potential complexity of both Pliocene and Pleistocene hominin technology (Pascual-Garrido & Almeida-Warren, 2021). This is central to commentaries from **Falk**, **Tzafestas**, and **Gallup & Eldakar**, who highlight that coordinated hunting strategies (also see Boyd & Richerson, 2022; Lang & Kundt, 2023; Stibbard-Hawkes, 2023), children's play objects (also see Lew-Levy, Andersen, Lavi, & Riede, 2022a) and organised team-competition (Turnbull, 1982) would each be traceless. Falk makes the case strongly, arguing that during the period of hominin evolution proceeding the Lomekwian (i.e., the "botanic age"; Falk, 2024), we should not assume technological nor cognitive stagnation despite the paucity of material evidence. Falk highlights the credible importance of infant-carrying slings among early bipedal hominins (see also Suddendorf, Kirkland, Bulley, Redshaw, & Langley, 2020; Wall-Scheffler, Geiger, & Steudel-Numbers, 2007; and, for critical discussion, Sterelny, 2021a). Slings are routinely manufactured from perishable media by both the Hadza and Mbuti for good reason – soft, pliable materials like leather and cloth are much better suited to carrying wriggly infants than are rigid bone or stone vessels. The absence of evidence for soft containers before 50,000 BP (reviewed Suddendorf et al., 2020) is therefore inferentially meaningless.

Numerous other important categories of material evidence suffer similar issues. For instance, **Sterelny** also proposes "Late Pleistocene hominins [probably] did not live in towns and villages (or work metal); a secure conclusion based on lack of evidence for settled lives (or metal working)." This appears true of metalworking and stone buildings, and also of large, densely populated towns which may leave signature patterns of mortuary remains and refuse. Concluding that settled lives were absent during the Pliestocene seems less sure. Many once-temporary Hadza camps have today become permanently occupied, characterised by wooden dwellings that use similar construction methods but are larger than traditional Hadza huts. These buildings do not incorporate earthworks or storage pits, and it is unclear whether, at greater time-depths, such settlements would be discernibly different from large, seasonally occupied camps. Indeed, there *are* multiple instances of sturdy wooden dwellings from Late Pleistocene Eurasia suggestive of settled or, minimally, semi-settled lives (al-Nahar & Olszewski, 2016; Maher, 2019; Maher & Conkey, 2019). The recent discovery of apparent joinery (Barham et al., 2023) from 476,000 BP might suggest semi-permanent wooden structures in the Chibanian (and see Singh & Glowacki, 2022). Determining settlement, occupation and mobility patterns from ancient remains is complex (Maher, 2019; Padilla-Iglesias & Bischoff, 2024) and beyond the scope of this reply. Yet all structures in the target article dataset are botanic, and good ethnoarchaeology exploring mobility-patterns (Padilla-Iglesias & Bischoff, 2024) and the different signatures left by semi-sedentary and sedentary camps (e.g., Kent, 1991; Yellen, 1977, 1991), may provide cause for caution in reasoning from absence.

R2.2. Condition 2: A probabilistic link between capacity and expression

It is **Sterelny**'s second claim about hafting, however, which I take more serious issue with: That its absence provides evidence that *H. heidelbergensis* lacked "the capacity to haft tools." Sterelny argues that if a capacity to make hafted tools were available, there would be a strong incentive to use them. "Capacity" can be construed in different ways and could simply mean "know-how." However, following the target article and Haidle's (2016) distinction between performance versus capacity (discussed by **Will**), I take it to mean intrinsic or underlying faculties; or some extension of cognitive faculties resulting from, for example, enmeshment in denser social networks (discussed in Sterelny, 2011, 2021b).

If so, with hindsight, it is easy to overestimate the likelihood that even "modern" minds would reinvent and retain particular technologies. Hafting not only requires knowing how to attach a stone to a stick, but knowing *that it can be done* and *why it would be useful*. The knowledge to create and efficiently use weapons technologies can be lost and, as **Milks** reminds us, hafting is not universal. Indeed, even "simpler" vital technologies have permanently left the repertoires of modern humans; fire-making requires two dry sticks and tinder (the hand-drill method), yet a recent ethnographic review revealed five cases where it was lost and not reinvented (McCauley, Collard, & Sandgathe, 2020). It is no surety that living *Homo sapiens* with the demonstrable capacity to produce and use hafted tools would probabilistically reinvent them. It is difficult to assess what cumulative cultural mountain ranges (see Lombard, 2016) must be navigated to invent hafting, or how this probability is influenced by social contexts (Sterelny, 2021b).

Weakening (perhaps breaking) the inferential link between capacity and production also weakens the probabilistic link between negative evidence and inference. This has broader

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implications. **Will** highlights the need for carefully constructed bridging theories, citing Coolidge, Haidle, Lombard, and Wynn (2016) as a blueprint. I strongly endorse this suggestion, with the caveat that when addressing capacity differences, we must be explicit and cautious about inferences we are drawing from negative evidence. Indeed, Coolidge et al. (2016) provide a case study. They investigate the distinct cognitive systems involved in the creation of hunting bows, linking them to episodic and working memory. Like **Sterelny** they also cast doubt on the capacity of *H. heidelbergensis* who, they contend, "probably could not have invented a bow and arrow, and almost certainly could not have conceived of, and organised, the entire system" (p. 224). However, beyond tentatively exploring *H. sapiens* comparative endocast data (Bruner, 2010; Schacter & Addis, 2007), they provide little evidence that *H. heidelbergensis* lacked these requisite capacities. The tacit implication (made explicit elsewhere; Fajardo, Kozowyk, & Langejans, 2023; Wadley, 2021) appears to be that technological difference indicates capacity difference, and that *H. heidelbergensis* lacked cognitive prerequisites for bow-making *because* they lacked bows. In building future bridging theories, we must make any inferences from absence explicit – perhaps even constructing negative bridging theories. We must not over-rate the probabilistic link between absence and capacity. We must not underrate the intelligence of past humans where evidence (positive **or** negative) is lacking. To achieve these aims, one path forward is changing our null model.

R3. Null hypotheses and prior beliefs

In reviewing the literature on comparative hominin cognition, the target article showed that researchers typically present evidence against the default assumption that other human species were less cognitively sophisticated than *Homo sapiens*: The "primitive null." After exploring the broadening consensus on hominin cognitive sophistication, the target article proposed a new null hypothesis: That all members of at least our genus had comparable capacities. Trying to reject this "cognitively modern" or [henceforth] "derived" null beyond reasonable doubt, I suggested, may bring expectations in line with the latent facts. Several commentaries **(Kuleshova et al.**; **Vasil**; **Milks**; **Liu & Stout)** endorsed critical reassessment of our null assumptions. Two commentaries (**Bedetti & Allen**; **Irurtzun**) questioned the wisdom of adopting this new proposed null. In fact, here, areas of genuine disagreement are minimal. Both commentaries afford opportunities to clarify what a revised null model might mean, and why it is useful even if ultimately proven incorrect.

R3.1. Balancing probabilities: The null model is a comparator not a conjecture

Bedetti & Allen characterise my position as (A) rejecting the assumption that earlier humans had different capacities and (B) extending "modern" cognitive capabilities to all members of our genus. I agree that this conclusion is unwarranted, but clarify that this is not my position. Although I believe, like many commenters (e.g., **Milks**, **Blessing**), that the difference between us and other human species is often overestimated, I do not believe there is presently sufficient evidence to accept a derived null (i.e., all members of our genus had similar capacities), or to definitively reject a primitive null (i.e., earlier members of our genus were less sophisticated). I must therefore explain what adopting a derived null means in practice.

It is important to appreciate that null hypotheses – inferential heuristics developed by early twentieth century statisticians (Fisher, 1928; Neyman & Pearson, 1928; Pernet, 2016) – are neither conjectures, conclusions, nor statements of prior belief. In frequentist *p*-value hypothesis testing, null hypotheses are used to calculate the probability of seeing the observed results given no genuine relevant relationship between variables of interest. Although *p*-values are becoming less prevalent in certain sciences (McElreath, 2016), even in Bayesian or informal inferential reasoning, null models still have utility as comparators. I provide an example from my own work.

I recently co-authored a study exploring eyesight (visual acuity) among the Hadza (Stibbard-Hawkes & Apicella, 2022). There is extensive evidence that increasing classroom education is associated, globally, with worsening distance vision (Ku et al., 2019; Morgan, French, & Rose, 2018; Mountjoy et al., 2018). We had data on Hadza school participation, so decided to investigate this relationship. Here, our hypothesis (H1) was that school participation should worsen distance vision, and our null hypothesis (H0) was that schooling should have no (or a positive) effect. After running analyses, we found no strong statistical evidence of a negative association between school participation and visual acuity (estimates were wide and crossed zero), and were unable to reject the null hypothesis. Note, though, this does not mean the null hypothesis is true (see Pernet, 2016). In fact, given the wider literature (Morgan et al., 2018), we should still expect schooling to worsen eyesight, and the absence of clear statistical evidence was probably consequence of a small sample with low school attendance. It could alternatively be, however, that there is some peculiarity of Hadza school-participation which diminishes (or reverses) its impact on eyesight. Here, by setting a high inferential hurdle, null hypothesis testing forces us to rely on hard evidence to support our conclusions, rather than accepting (reasoned) conjecture.

Like both **Bedetti & Allen** and **Irurtzun**, I find it most parsimonious (see McGrew, 2010) that earlier members of both our lineage and our genus did not have brains, minds and cognitive capacities identical (Boeckx, 2023; Meneganzin & Killin, 2024) to ours. Adopting a "cognitively modern" null is wholly compatible with this belief. The new null model simply changes the inferential bar we must clear. As **Vasil** highlights, it prevents the more parsimonious primitive/ancestral null from being tacitly accepted, and forces us to think clearly about how differences would manifest using a probabilistic "evidence-based approach" (see Bedetti & Allen; **Liu & Stout**). Compared to the primitive null, a "derived"/"cognitively modern" null *raises* that evidentiary burden of proof.

R3.2. Beyond reasonable doubt: Overturning the derived null requires extraordinary evidence

Irurtzun argues that adopting a derived null would raise the burden of proof so high it "may amount to a scientific dead-end." Although it might not be currently possible to conclusively overturn the derived null, it is not a dead-end. Instead, it forces us to employ multiple categories of probabilistic evidence, and appreciate their limitations.

Irurtzun cautions that no artefact would definitively show any particular human species did not possess any particular cognitive trait or capacity. This may be true. Although, as discussed in section R.2, there are instances where we may update beliefs in light of the absence of certain artefacts (e.g., modified ochre, metals, hafted stones), most allow only limited probabilistic inferences concerning capacity difference (target article, sect. 10.1). Other authors may put more stock in the inferential utility of absent artefacts (Coolidge et al., 2016; Sterelny, 2014), for instance interpreting correlations between encephalisation and toolkit complexity as causal (**Bedetti & Allen**) rather than parallel. Even so, in disproving the derived null hypothesis (H0), we must be explicit about the probabilistic (Irurtzun; **Liu & Stout**; **Will**) inferential utility of the evidence, both positive and negative. If our aim is to get closer to the truth, properly reckoning the weaknesses of artefactual data is no bad thing.

Irurtzun also cautions that to overturn a derived null we could only rely on negative, not positive evidence. However, there are several types of enduring positive evidence we can employ. **Bedetti & Allen** highlight one of them: Brain size. The relationships between (relative) brain size, capacity and behaviour are complicated. Much research including, notably, certain formulations of the Upper Palaeolithic transition model, assume that fundamental reorganisations of brain structures could occur without large shifts in endocranial volume (e.g., Gabora & Smith, 2019; Klein, 1995). Recent work, focusing on *Homo naledi*, has reached similar conclusions from the opposite vantage, suggesting that small brains need not prohibit "symbolic" behaviour (Berger et al., 2023; Fuentes et al., 2023; though see Foecke, Queffelec, & Pickering, 2024). I am sympathetic to Bedetti & Allen's view that, as brain tissue is costly, inter-species size differences must serve some adaptive function. The fact that different brain tissues may be asymmetrically costly (Castrillon et al., 2023) complicates but does not obviate this supposition. Indeed, skeletal evidence of this type can reasonably be taken as positive probabilistic evidence against the derived null. The question is how and to what extent? What particular capacities do the approximately 500–700 cubic centimetres of cranial expansion that differentiate us from early members of our genus enable?

Presently, secure answers to this question may be beyond reach. The link between large brains and "symbolism," at least, is not secure. Although the *H. naledi* data may not be sound (see Foecke et al., 2024; Martinón-Torres, Garate, Herries, & Petraglia, 2023), **Verpooten & De Tiège** and **Tennie & Planer** show us that many material features often associated with complex symbolic cognition in archaeological contexts – acoustic technologies, non-utilitarian decoration/marking, and manuports – are produced by species less encephalised than any ancient human. From the other direction, **Ben-Oren et al.** speculate that cognitively modern humans need not create any complex or symbolic artefacts at all (*contra* **Barceló-Coblijn**). The connection between large brains and language is also tentative and complicated (Albessard-Ball & Balzeau, 2018, **Kuleshova et al.**).

As **Kuleshova et al.** highlight, there are other categories of positive evidence, though none are definitive. Cranial anatomy (Kochiyama et al., 2018) and endocasts (Bruner, 2010; de León, Bienvenu, Akazawa, & Zollikofer, 2016; Labra et al., 2024; Mounier, Noûs, & Balzeau, 2020; Schacter & Addis, 2007) may provide scant clues about the relative expansion of different cortical structures, although their utility is limited (Neubauer, 2014) and open to multiple interpretation (Labra et al., 2024; Mounier et al., 2020). Other anatomical features – laryngeal or ear morphology – may provide clues about language, though most important features are soft tissues; evidence remains inconclusive (discussed in Albessard-Ball & Balzeau, 2018) and often suggests continuity (Conde-Valverde et al., 2021). For younger hominins, ancient DNA and comparative genomics show more promise. Present studies offer only associational hints (Kuhlwilm & Boeckx, 2019; Pauly, Johnson, Feltus, & Casanova, 2024; Skov et al., 2022) and, as **Blessing** warns us, many genotype–phenotype association studies are badly confounded. Yet, as the field advances, and as comparative genomics (Jorstad et al., 2023; Suresh et al., 2023) and our knowledge of the causal pathways between genotype, ontogeny and phenotype improve over the next century, positive genetic evidence may one day allow us to overturn elements of the derived null. Again, setting a higher hurdle forces us to be precise about the limitations of existing evidence.

This does not represent an inferential "dead-end" – instead we must adopt as many categories of evidence, positive and negative, as possible. If we are unable to prove beyond reasonable doubt that other members of our genus were not similar in capacity to ourselves, it may temper beliefs about species-level capacity differences.

R3.3. Until proven guilty: Failing to overturn the derived null will temper our biases

As **Irurtzun** tells us "a certain homogeneity of traits is a core assumption for intra-species groupings." This is correct, and one of several *a priori* reasons why we should hesitate to ascribe material culture differences within our species (e.g., Gabora & Smith, 2019; Kelly, Mackie, & Kandel, 2023; Klein, 1995) to differences in capacity (see McBrearty & Brooks, 2000). Irurtzun also warns that we cannot extend the same logic beyond intra-taxon groupings. **Bedetti & Allen** ask "why place the boundary of *Homo-sapiens*-level cognition at [the genus level] rather than another?" Here, the reply to both is the same: Our genus *is* an intra-taxon grouping. Although less similar than members of the same species, a certain homogeneity of traits is a core assumption for genus-level groupings also. We should not expect similarities to cease above the neck. It is easy to forget this, and the derived null provides a heuristic check on our biases.

Here, **Bedetti & Allen** draw useful parallels between the present discussion and debates from comparative animal cognition. They highlight Morgan's canon, a parsimony heuristic which cautions no animal activity should be interpreted in terms of higher-order cognitive processes when it may be explained by less complex ones. Morgan's canon is a useful check on the "romantic" (*sensu* Dennett, 1983) tendency to anthropomorphise non-human animals. It is seen at work in commentaries by **Tennie & Planer** and **Verpooten & De Tiège** (also Tennie, Bandini, van Schaik, & Hopper, 2020). The opposite to Morgan's canon is perhaps Macphail's null, which posits we should, by default, assume *no* differences in intelligence between species (Macphail, 1987; Macphail, Barlow, & Weiskrantz, 1985). Macphail argued that different species often employ similar general processes of associative learning (Macphail & Bolhuis, 2001; Macphail et al., 1985) and that between-species differences in task performance often result from contextual factors (Macphail et al., 1985). For instance, in early vocal language acquisition studies, apes failed to master vocabularies of over a few utterances, but when researchers switched to gestural communication or lexigrams, representatives of those same species were able to learn large (100–1000) vocabularies (Gold & Watson, 2018; Patterson & Cohn, 1990; Savage-Rumbaugh, Shanker, & Taylor, 1998) alongside elements of syntax (Savage-Rumbaugh et al., 1998). The difference was context, not capacity.

There are many instances where Macphail's null has been rejected (Bastos & Taylor, 2020). Macphail himself was hesitant

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to ascribe human-like intellect to non-human animals (Macphail et al., 1985). When Macphail's ideas were published in a target article (Macphail, 1987), commenters were sceptical, yet almost 40 years later, the heuristic continues to provide a check on confirmatory biases in designing and interpreting behavioural experiments (Bastos & Taylor, 2020; Pepperberg, 2020). Where Morgan's canon provides a check on anthropomorphism, Macphail's null provides a check on anthropocentrism. The question is, when comparing our capacities with those of other humans, where does the prevailing bias lie?

Early Western anthropologists at least were characterised by the tendency to view themselves as exceptional. The target article highlighted endemic early twentieth century discrimination against hunter-gatherer populations (Woodburn, 1997), which had its basis in technological differences (Bagshawe, 1925; Blurton Jones & Konner, 1989) and was central in shaping policy (McDowell, 1984). **Milks** instantiates similar biases in discussions of the Tasmanian toolkit, including Noetling's (1911) suggestion that their "failure" to add stone points to spears indicated the lack of a modern mind. This juxtaposes uncomfortably with present discussions of *H. heidelbergensis* hafting (sect. R.2). Although progress has been made, and work by Sahlins (1972) and Woodburn (1982) has helped ameliorate such biases, they continue colouring perceptions (Lavi, Rudge, & Warren, 2024). Indeed, one commentary (**Sergiou & Gabora**) questions whether contemporary hunter-gatherers should be considered just as cognitively sophisticated as other humans (*contra* **Blurton Jones**).

It is difficult not to see parallels (Shea, 2011; Zilhão, 2014) between shifting twentieth century conceptions of hunter-gatherer minds and more recent discourses surrounding the "sapience" of ancient humans. Slimak (2024) gives an evocative example of a leading Russian academy of science member declaring that Neanderthals "have no soul," a question that has occupied academic theologians (Gaine, 2021; Moritz, 2012, 2015). This is an extreme example that yet throws light on "unspoken, unconscious assumptions which underlie great swathes of our understanding of this humanity" (Slimak, 2024, p. 12). Meneganzin and Killin (2024) explore how "aesthetic capacity" was long considered unique to *Homo sapiens* (and see Slimak, 2024, Ch. 5). **Blessing** highlights the related fact that categories of artefact which were once accepted as evidence of *H. sapiens*' behavioural modernity are routinely dismissed in Neanderthal contexts (also see target article, sect. 4 & 16).

Given the outcomes of Western exceptionalism during the nineteenth and twentieth centuries (Elkins, 2022), such comparison inevitably takes on a moral aspect. Equally pertinent here though, is that anthropocentrism (perhaps *sapiens*-centrism) has routinely and demonstrably diminished the predictive accuracy of our theories: In the 1990s and 2000s, research consensus held that modern capacities appeared after the origins of our species (Klein, 1995), an idea that receives continuing attention (Gabora & Smith, 2019; Kelly et al., 2023; Klein, 2017). Earlier African evidence (McBrearty & Brooks, 2000) paved the way towards overturning this consensus. In the 2000s and 2010s, research consensus held that Neanderthals were less cognitively capable than *H. sapiens*. Increasing material evidence (Fajardo et al., 2023; Hardy et al., 2020; Hoffmann et al., 2020; Mazza et al., 2006; Meneganzin & Killin, 2024) has led to a reassessment and the newly emerging consensus that Neanderthals, if not indistinguishable, were not "inferior" (Hardy et al., 2020; Mazza et al., 2006; Meneganzin & Killin, 2024; **Blessing**). Today, we still assume capacity differences between ourselves and middle Pleistocene hominins (Coolidge et al., 2016; Metcalfe, 2023; **Sterelny**), which emerging evidence is only beginning to throw into contention (Barham et al., 2023). Although, as **Liu & Stout** emphasise, discussions are greatly more sophisticated today than the turn of the millennium, there is a pattern, and we may not yet have escaped the "modern human superiority complex" (Villa & Roebroeks, 2014).

Recognising these biases is particularly important in cases where evidence is unlikely to preserve. The temporal isolation of the various wooden artefacts (Barham et al., 2023; Belitzky, Goren-Inbar, & Werker, 1991) probably reflects preservation not expression. **Falk** reminds us that we should not underrate cognitive sophistication during the first half of hominin evolutionary history either; even though preservation biases mean we may never find secure evidence of most technologies. Here the derived null may be profitably extended beyond our genus to our whole lineage – although as we approach the base of the clade, arguments of homology become more relevant (discussed in McGrew, 2010; Sayers & Lovejoy, 2008; Sayers, Raghanti, & Lovejoy, 2012).

The derived null, as above, is not conjecture, nor a statement of prior beliefs. We may still improve inference by strategically adopting weakly (Lemoine, 2019) or more strongly (Lee & Vanpaemel, 2018) informative priors which depart from our null. Instead, the derived null offers both a perspective shift, and a challenge. In failing to overturn it, and in reflecting upon that failure, we might moderate our beliefs somewhat. If we are ever to overturn it beyond reasonable doubt, we must leverage all available evidence.

R4. Jingling all the way? The role of hunter-gatherer research

The target article explored three material datasets compiled from hunter-gatherer ethnographies (Marlowe, 2010; Smith, 1977; Tanno, 1981; Woodburn, 1970), augmented with direct observation. These demonstrated that even contemporary humans need not necessarily leave enduring evidence of complex technology – particularly, symbolic behaviour. The target article applied these lessons to interpretations of the past.

One commentary (**Protzko**) warns that using toolkits from contemporary hunter-gatherers to reason about the past may draw a false equivalency, cautioning that things with similar names (i.e., hunter-gatherers) need not share further similarities: the jingling fallacy. This demurral bolsters a large cross-disciplinary literature questioning the over-application of contemporary ethnography in reconstructions of the past (discussed in Graeber & Wengrow, 2021; Lieberman, Tooby, & Cosmides, 2007a; Pargeter, MacKay, Mitchell, Shea, & Stewart, 2016; Schrire, 1980; Singh, 2022; Singh & Glowacki, 2022; Solway, Lee, & Barnard, 1990; Wilmsen & Denbow, 1990; Wobst, 1978).

I am sympathetic to **Protzko**'s concerns. Just as it is easy to constrain our conception of past material complexity to enduring material evidence (**Falk**; **Tzafestas**), it is easy to constrain our conception of past hunter-gatherer lifeways to contemporary ethnographic evidence (Pargeter et al., 2016; Singh & Glowacki, 2022). There is cause for vigilance here and past critiques remain relevant. Indeed, issues of ethnographic modelling have been central to ongoing debates about gendered Palaeolithic foraging practices (Anderson, Chilczuk, Nelson, Ruther, & Wall-Scheffler, 2023; French, 2024; Lacy & Ocobock, 2024; Ocobock & Lacy,

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2024; Venkataraman et al., 2024). We should not blindly assume similarity.

There is evidence of at least some material similarity between certain contemporary hunter-gatherers and certain mid/upper-palaeolithic hunter-gatherers. **Barceló-Coblijn** highlights similarities between 75,000-year-old engravings from Blombos Cave SA (Henshilwood & Dubreuil, 2009) and the intricate lattice-like patterning of Mbuti barkcloth (Tanno, 1981) – although, given that these patterns are not produced by all foragers (see supplementary data of the target article), the parallels could be coincidental. More securely, certain technologies (d'Errico et al., 2012) and elements of arrow design (Backwell et al., 2018) are similar between ancient South African hunter-gatherers and contemporary Kalahari foragers, perhaps in consequence of cultural transmission and selection against deviations in tool design. The earliest Australian wooden artefact, fat-daubed ritual sticks, bears more-than-coincidental similarity to those used in ethnographically recorded *mulla-mulla* rituals, indicating perhaps 12 millennia of uninterrupted, high-fidelity cultural transmission (David et al., 2024).

Yet, although occasional similarities exist, it is likely that past toolkits, even in similar ecologies, were substantially different to those of today. However, the central lesson of the current discussion – that contemporary humans need not leave enduring evidence of technological complexity – does not require particular similarity between the toolkits of contemporary and past foragers. Indeed, in consequence of demography (Hovers & Belfer-Cohen, 2006), cumulative culture (Lombard, 2016) and the ratchet effect (discussed in Tennie, Call, & Tomasello, 2009) as we go further back in time, we are *less* likely to see enduring evidence of material complexity. The point is that material differences, such as those between Upper Palaeolithic Australia (Brumm & Moore, 2005), the Levant (Belfer-Cohen & Hovers, 2010) and Europe (Kelly et al., 2023), or between *H. sapiens* before and after 100 KYA (Gabora & Smith, 2019; Kelly et al., 2023), or between human species (Meneganzin & Killin, 2024), need not imply cognitive capacity differences. As **Ben Oren et al.** remind us, this supposition is well-supported by the archaeological record. Present data from contemporary African foragers merely instantiate this broader issue.

R4.1. Comparative hunter-gatherers anthropology reveals broader trends in behaviour

Although the thesis of the target article requires no particular similarity between the toolkits of contemporary and Palaeolithic hunter-gatherers, similarities go beyond shared nomenclature: All hunter-gatherers hunted and gathered. Contemporary hunter-gatherers are not atavisms, nor relics, but modern, living populations, situated within and increasingly integrated into (Pollom, Cross, Herlosky, Ford, & Crittenden, 2021; Stagnaro, Stibbard-Hawkes, & Apicella, 2022) global market systems. Some of my Hadza collaborators, who continue to forage, today have phones, and post videos on Facebook. My subject area, Human Behavioural Ecology, should better recognise this, but is not predicated on contemporary foragers being identical to past ones. Instead, it relies on a probabilistic gambit similar to that used by **Sterelny**; that rational people, faced with similar economic or ecological challenges, will converge on similar solutions (Blurton Jones, 1982; Borgerhoff Mulder & Schacht, 2012; Cronk, 1991; Cunningham, 2003; Kelly, 2013; Layton, 2001; Mace, 2014; Marlowe, 2004; O'Connell, 1995; Wiessner, 2022). This is supported by evidence that many forager groups globally converge on similar patterns of behaviour (Bird & Codding, 2015; Grove, 2009; Hoffman, Farquharson, & Venkataraman, 2023; Kelly, 2013; Smith et al., 1983; Woodburn, 1982) despite having no recent shared history.

It is possible to overextend hunter-gatherer referential models beyond their utility, and the approach has numerous detractors (Gosselain, 2016; Graeber & Wengrow, 2021; Pargeter et al., 2016; Schrire, 1980). Moreover, Human Behavioural Ecology underrates the role of cultural processes (discussed in Mace, 2014) and, like analogous utility maximisation models from behavioural economics (Hodgson, 2012), over-rates human rationality more generally. People do not inevitably find optimal solutions or technologies (sect. R.2). Yet, where hard evidence is lacking, if employed with appropriate caution, forager studies may still help us reason about the unknown.

This discussion has explored what we can infer from the presence and absence of different materials. Ethnoarchaeology must have a continuing role here (Lane, 2014; Yellen, 1977). Where the present dataset only analyses artefact repertoires, studies of abandoned camps may provide information on the frequency and footprint of different artefactual traces (Yellen, 1977; O'Connell, Hawkes, & Jones, 1991). Ethnoarchaeology can also tease apart the subtle difference in both site organisations, and refuse production that characterises mobile and more sedentary camps (Kent, 1991, 1996; Yellen, 1991). Computational models, validated by ethnographic data, can explore the role of population structures in shaping and maintaining toolkit diversity (Ben-Oren, Kolodny, & Creanza, 2023a; Premo, 2015; Zonker, Padilla-Iglesias, & Djurdjevac Conrad, 2023), and how mobility shapes and limits the available evidence (Padilla-Iglesias & Bischoff, 2024). Ethnoarchaeology is also key to exploring how mobility, environment, network structures and functional constraints predictably influence the design, variation and expression of different technologies (Collard, Kemery, & Banks, 2005; Padilla-Iglesias et al., 2024; Shott, 1986; Wiessner, 1983).

Hunter-gatherer ethnography may also help us reason about patterns of behaviour and material expression which leave *no* traces. Several commentaries provide examples (**Falk**; **Gallup & Eldakar**; **Tzafestas**; **Vasil**). As Gallup & Eldakar and Tzafestas show us, the ethnographic record is replete with accounts of team competition (Sutton-Smith & Roberts, 1971) and play that leave no enduring signature. For instance, the Mbuti often participated in organised, ritualised tugs-of-war (Turnbull, 1982). Although Hadza ethnographers have documented gambling games ("Lukuchuko," see Woodburn, 1970), there are few accounts of physical competition beyond those organised by researchers (Blurton-Jones & Marlowe, 2002; Stibbard-Hawkes, Amir, & Apicella, 2023; Stibbard-Hawkes, Attenborough, & Marlowe, 2018). Yet, anecdotally, I have witnessed three impromptu Hadza physical skills contests: An archery contest between two men; a baobab climbing race; and an impromptu pull-up competition. We should assume these are ethnographically under-reported. Research into the functional role (Cohen, Davis, & Taylor, 2023; Cohen, Ejsmond-Frey, Knight, & Dunbar, 2009; Gray, 2009; Lew-Levy, Reckin, Lavi, Cristóbal-Azkarate, & Ellis-Davies, 2017; e.g., in cooperation, pedagogy and group cohesion), and ethnographic contexts of competition and play among both children (Lew-Levy et al., 2022b; Lew-Levy, Boyette, Crittenden, Hewlett, & Lamb, 2020) and adults (Gray, 2009), allows us to build provisional models of past behaviour.

Vasil also discusses the centrality of ethnography in exploring the cognitive demands of group hunting, especially persistent hunting (also see Lieberman, Bramble, Raichlen, & Shea, 2007b; Morin & Winterhalder, 2024). Shared intentionality and group hunting have also featured in models of ritual evolution (Lang & Kundt, 2023). Here, remembering Morgan's canon (Stibbard-Hawkes, 2023) cautioned that cooperative hunting is found in non-human species (Boesch, 2002; Stander, 1992), and emphasised that not all contemporary foragers engage in extensive cooperative hunting (Berbesque, Wood, Crittenden, Mabulla, & Marlowe, 2016; Wood et al., 2021). Moreover, there is debate over the past prevalence of persistence hunting (Morin & Winterhalder, 2024; Pickering & Bunn, 2007). Nonetheless, cooperative hunting, especially drive hunting, is common globally (Boyd & Richerson, 2022), including among the Mbuti (Wilkie & Curran, 1991). It probably has deep roots. Ethnographic analogy is vital for exploring the forms hunting might have taken in the past and the contexts in which different practices were adaptive (Codding, Bird, & Bird, 2011; Hoffman et al., 2023; Stibbard-Hawkes, Attenborough, Mabulla, & Marlowe, 2020; Winterhalder, 1986).

Last, **Grüning & Grüning** propose a model for comparing the material complexity of different societies, focusing on assemblage diversity, artefact design complexity and the functional necessity of artefacts. Here, as **Falk** argues, we should expect that much complexity will be expressed only in perishable media (target article, p. 12). Material datasets like those in the SI file (or see Buckley, 2023) may allow us to calibrate such models, by comparing estimates of material complexity derived from complete repertoires to those derived only from enduring artefacts. These two estimates might differ. Indeed, as **Sergiou & Gabora** conclude "our ancestors may have been much more creative than what we can surmise from the existing archaeological record." Although we must remember that the ethnographic record represents only a recent and limited sampling of the full sweep of modern human diversity, it remains the primary source for setting expectations and mapping the latent shapes of past creativity.

R4.2. Hunter-gatherers, materiality and cognitive ecologies

Several commenters highlight both that artefacts are imbedded in social contexts (e.g., **Ben-Oren et al.**; **Sterelny**; **Sergiou & Gabora**) and that objects and materials may influence and extend our social and cognitive worlds (**Di Paolo et al.**). This has been called "materiality" (Hussain & Will, 2021) or, more holistically, "cognitive ecology" and the "extended mind" (Sterelny, 2019; Tribble & Keene, 2011). Several commentaries provide a chance to further explore the prospects and potential pitfalls of these approaches with reference to contemporary hunter-gatherers.

First the pitfalls. The target article warns against assuming strong boundaries between cognitive ecologies, especially where doing so creates "a hierarchy of cultural forms" or classifies "some as more cognitively or behaviourally modern [or] complex… than others" (p. 17). Sergiou & Gabora's commentary provides opportunities to revisit this. They question whether there is sufficient evidence that living hunter-gatherers are just as cognitively sophisticated as other societies and highlight that "cognitive sophistication is not uniform even amongst contemporary human populations." They emphasise the concept of "nous," meaning "intellect, understanding, or reason," and ask whether "contemporary foragers differ from other contemporary human populations with respect to either nurture or nous, and even differences due to nature." Here I implore caution.

It is true that reason is mediated by cultural context (Henrich, Heine, & Norenzayan, 2010; Reuning, 1972). As Henrich et al. (2010) relate, Kalahari foragers are much less susceptible to Müller-Lyer "arrow-and-stick" illusions than north Americans. Likewise, the Hadza language does not have an extensive native counting system so, to ease comprehension, researchers have often translated numbered Likert-scales into vernacular language (e.g., Smith & Apicella, 2022; Stibbard-Hawkes et al., 2024). However, despite patterning by subsistence type, differences in reasoning are task-specific. **Blurton Jones** highlights the difficulties that Western anthropologists face navigating the nuanced web of expectations that characterise hunter-gatherer sharing and personal property relations (Bahuchet, 1990; Crittenden & Zes, 2015; Lee, 2011; McCall, 2000; Peterson, 1993; Stibbard-Hawkes, Smith, & Apicella, 2022; Woodburn, 1998). Several studies describe the complex deductive logic involved in interpreting animal spoor, or the deep factual knowledge hunters have about animal behaviour (Blurton Jones & Konner, 1989; Stibbard-Hawkes et al., 2018). Given the innumerable domains of life where we bring reason ("nous") to bear, while we may compare task-specific performance, satisfactorily operationalising and comparing the "cognitive sophistication" of whole societies is unachievable, perhaps meaningless (discussed in Buckner, 2022; Reuning, 1972).

Moreover, culturally mediated differences in "nous" are neither fixed nor bounded. Presently, I am working over e-mail with a Hadza collaborator – who grew up in the bush – on the cognitively demanding task of research methods, design and translation. Just as he has, in adulthood, acquired the technological and linguistic skills to do this complex work, so might I, with practise, learn the nuances of spoor identification (Blurton Jones & Konner, 1989). The lesson, again, is that we should not overemphasise cultural boundaries, which are permeable. As for cognitive differences between hunter-gatherers and others "due to nature" (**Sergiou & Gabora**), such inquiry is impossibly confounded by context and ontogeny. As **Blessing** emphasises, the topic has been the purview of junk scientists (see Sear, 2022), and prone to malappropriation (Panofsky, Dasgupta, & Iturriaga, 2021). It has no place in this discussion.

If these pitfalls are avoided, we gain much by investigating inter-contextual patterning in the ways minds are extended by the materials we use, and material repertoires are shaped by context. **Di Paolo et al.** explore how certain materials may influence reasoning. They propose that non-perishable objects might last longer as design referents (e.g., via retrieval from abandoned camps, see Padilla-Iglesias & Bischoff, 2024), and that branch-weaving might foster skills such as tool disassembly, reassembly and component replacement. **Ben-Oren et al.** and **Sterelny** consider how social context might influence toolsets. Sterelny explores how denser social networks might increase the utility of social identity symbols (Kuhn & Stiner, 2007a). He suggests that shell beads make particularly useful identity markers (Kuhn & Stiner, 2007a; Miller & Wang, 2022). Ben-Oren et al. discuss the related idea that material symbols play some functional role in intra-group social cohesion (e.g., McElreath, Boyd, & Richerson, 2003), and so may be more prevalent among denser or more interconnected populations (Bar-Yosef, 1997; Hovers & Belfer-Cohen, 2024; Miller & Wang, 2022).

These are each topics where forager ethnography can provide insights. It can contextualise how material objects are situated in particular ecologies or social contexts (Riede, Lew-Levy, Johannsen, Lavi, & Andersen, 2023; Skaanes, 2017; Sterelny, 2021c; Wiessner, 1983, 1984). Quantitative cross-cultural research

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(e.g., Collard, Buchanan, Morin, & Costopoulos, 2011; Riede et al., 2023), may test hypotheses statistically – for instance, investigating the relationships between demography, population structure and symbol-use. Here while the present analysis did not include demographic variables (**Sergiou & Gabora**), other studies have explored the relationship between demography and "toolkit complexity" (see Ben-Oren, Strassberg, Hovers, Kolodny, & Creanza, 2023b; Kline & Boyd, 2010). It would be fruitful to explore the relationship between population size and structure and the intensity and design of semiotic artefacts across cultures. Here, we must not assume living foragers are facsimiles of the past, and appreciate that similar artefacts can take on different semiotic functions (Barker, Power, Heap, Puurtinen, & Sosis, 2019; Ozaita, Baronchelli, & Sánchez, 2022; Wiessner, 1983). Yet, where we prove that humans probabilistically respond to environmental and demographic challenges in predictable ways, we may go beyond jingling.

R5. Straw or stone?

Two commentaries (**Liu & Stout**; **Sergiou & Gabora**) caution that the target article overlooks recent paradigm shifts in the archaeological sciences. Liu & Stout, particularly, argue that the target article employs straw-man arguments, and that we should move "beyond critique." It is correct that the difficulties identified in the target article are not universal, nor characteristic of the whole field of Archaeology. Far from it. Neither, however, are they straw-men. In this section, I address these concerns, then explore how the dataset might be useful, even to those well-versed in the inferential limitations of the material record. I begin with three straightforward clarifications.

R5.1. Clarifications

First, **Liu & Stout** caution that the target article "downplays widespread critiques of the 'behavioral modernity' construct over the past two decades"; but the target article provides extensive discussion of these important critiques (e.g., see sect. 3, 4, 13, 14, 15 and 16) and highlights multiple (40 +) sources questioning either the soundness of the behavioural modernity concept or elements of its evidentiary basis, or related critical discussions of the evidence beyond our species (e.g., Albessard-Ball & Balzeau, 2018; Ames, Riel-Salvatore, & Collins, 2013; Baquedano et al., 2023; Botha, 2008, 2010; Breyl, 2021; Brumm & Moore, 2005; Conard, 2015; d'Errico & Stringer, 2011; d'Errico, 2003; Dibble et al., 2017; Haidle, 2016; Henrich, Kline, Muthukrishna, Shennan, & Thomas, 2016; Henshilwood & Dubreuil, 2011; Hoffmann et al., 2020; Hopkinson, 2011; Kuhn & Stiner, 2007b; Langley, Clarkson, & Ulm, 2011; McBearty, 2013; McBrearty & Brooks, 2000; McBrearty & Stringer, 2007; Milks, 2020; Mounier et al., 2020; Nowell, 2013; Pascual-Garrido & Almeida-Warren, 2021; Powell, Shennan, & Thomas, 2009; Scerri & Will, 2023; Scerri et al., 2018; Shea, 2011; Speth, 2004; Sterelny, 2014, 2011, 2016, 2021b, 2019; Stringer, 2002; Villa & Roebroeks, 2014; Zilhão et al., 2010; Zilhão, 2007).

Second, **Liu & Stout** warn that the target article "amplifies unilinear and teleological views of cognitive evolution and erroneously portrays them as consensus." This is a misreading. The target article does caution against teleological reasoning (orthogenetic evolution), but does not portray such views as consensus. Instead, it states that while popular accounts (e.g., Harari, Vandermuelen, & Casanave, 2020) falsely present recent origins models "as a resolved consensus theory… Within the academy, recent origins and 'revolution' theories have been vigorously debated… research consensus has leaned 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… have become more widely accepted" (target article, sect. 3).

Third, **Sergiou & Gabora** and **Liu & Stout** both highlight the role of McBrearty and Brooks' seminal paper "The revolution that wasn't." As **Will**; **Blessing** and **Blurton Jones** also note, this paper was critical in advancing the study of behavioural modernity beyond eurocentric "revolution" models. Its significance should not be understated. It is important also to clarify that the target article makes a different contribution. McBrearty and Brooks (2000) reviewed the African archaeological record and demonstrated, decisively, that material complexity had deep roots. They promoted a gradualistic framework for understanding cognitive evolution. The target article, instead, contends that because contemporary humans need not leave extensive evidence of material sophistication, we should be more cautious in using material culture as a barometer for cognition.

As **Blessing** tells us, present findings do have relevance to "rubicon" definitions of behavioural modernity: "Any generalized threshold for what counts as modern, or… what it takes to be human, will [probably] exclude some populations." "The assumption that we will eventually find the one difference between us and not us (e.g., Meneganzin & Currie, 2022), will always lead to… moving of the goal posts" (Blessing, 2023) so, as **Liu & Stout** emphasise, we must continue developing "approaches not organized around sterile… modern/pre-modern binaries." However, the target article is not primarily a critique of the "behavioural modernity" concept, but aims to inspire reconsideration of the link between material culture and complex cognition more broadly.

This is no straw-man.

Indeed, Killin and Pain (2021) highlight that using stone artefacts to infer aspects of human cognitive and social evolution is "the core business of evolutionary cognitive archaeology" (p. 269). A central assumption is that "complex technologies over the last 3.3 million years provide a mirror to the cognitive developments that underpin behavioral changes" (Fajardo et al., 2023, p. 1). Wynn, Overmann, and Malafouris (2021), in reviewing 50 years of research, characterise most as united in assuming that "bigger brains made better tools" (p. 99). Although models are often multifaceted and nuanced, as **Will** puts it, many continue to draw "straightforward connections between material culture and specific measures of cognitive capacities or behavioral complexity." Sections 3 and 4 of the target article give numerous recent examples, with quotations and page numbers. Although many were caveated (e.g., Kelly et al., 2023, is exemplary), they yet employed those broader modes of inference under consideration. Here I highlight three further recent examples:

Backwell et al. (2018) tell us "Complex cognition emerged approximately 100kya" (p. 290). They link this to hunting technology, stating "the bow and arrow is thought to signal higher-level cognitive functioning and is considered a hallmark of complex modern human behaviour" (p. 290). But not all humans use bows (Davidson, 1936; Stibbard-Hawkes, 2020).

Mithen (2024a) argues that Neanderthals frequently suffered injuries "from close-encounter hunting using thrusting spears" which "could have been avoided by using bows and arrows or thrown spears." He takes this as evidence that they "did not design hunting weapons for killing specific types of animals in specific circumstances" and so "struggled to connect the different semantic clusters of words within their brains, such as those relating to animals, people and tools." But there is evidence of contemporary humans – fully capable of connecting semantic clusters – hunting large, dangerous animals with hand-spears (Ichikawa, 2021; Macphail, 1930). The Mbuti, for instance, use hand-spears in elephant hunts (Ichikawa, 2021), which are better suited to immobilising an elephant's knees, and slashing its vulnerable lower abdomen, than are projectiles. Moreover, as **Milks** reminds us, it is easy to underrate the complexity of ostensibly "simple" technologies; creating non-hafted weapons, such as wooden long-spears, requires multi-step advanced woodworking techniques (Haidle, 2009; Leder et al., 2024; Milks et al., 2023), alongside years of learning (and teaching) to utilise effectively (Lew-Levy et al., 2022b). We should not dismiss these as "little more than a pointed stick" (Mithen, 2024b).

Although these two examples concern single artefact categories, **Sergiou & Gabora** highlight that much contemporary research is "multi-pronged" and "focuses on identifying adaptive packages of features." For example, Gabora and Smith (2019) identify a major transition at 100 kya during what they consider "was likely a time of major neural reorganization" (p. 226). They highlight seven features that identify this transition: (a) Proliferation of task-specialised tools; (b) "elaborate burial sites indicating ritual"; (c) "personal symbolic ornamentation"; (d) representational cave-art; (e) complex hearths and structured living spaces; (f) calorie-gathering intensification; and (g) "bone and antler tools, sometimes with engraved designs." They propose these changes resulted from "a fine-tuning of the biochemical mechanisms underlying the capacity to spontaneously shift between different modes of thought" (p. 227). Yet, as here, even where models are multi-pronged, we may still reconsider the inferential utility of one or other category of evidence. That contemporary humans – well capable of shifting between modes of thought – do not universally engage in elaborate ritual burial (target article, sect. 10, para. 3), or produce representational cave-art (target article, sect. 10, para. 2), or leave enduring evidence of personal symbolic ornamentation (target article, sect. 10.1) is surely relevant.

It is best to view this, as **Liu & Stout** remind us, not as a binary discussion over truths and falsehoods, but "as a disagreement about probabilities." We must, however, recognise this disagreement as genuine.

R5.2. Prescriptions

I am nonetheless sympathetic to **Liu & Stout**'s call to "move on from critique." Scepticism from beyond the field is nothing new (Lewontin, 1998). Although the dataset is novel, as **Will** reminds us, many of the inferential problems identified here are well-known to Cognitive Archaeologists (reviewed in Killin & Pain, 2021); and will appear trivial to some readers. Despite this, data-driven critical discussion remains important.

First, while certain issues are well-known, contextualising abstract lessons with hard data from living humans makes them tangible. It is easy, when thinking hypothetically about long-dead humans, to speculate that the hunting bow is "a hallmark of complex modern human behaviour"; but reflecting on the many complex, modern humans who do not produce them (Stibbard-Hawkes, 2020) may inspire researchers to moderate these and related claims. Theoretical diversity is valuable (Killin & Pain, 2021) and inter-disciplinarity allows the synthesis of insights from different fields. Even where the target article provides little novel discussion, the data might still lead to a modest reassessment of the probabilistic inferential utility ascribed to certain types of material evidence.

Second, as **Will** identifies, *Behavioural and Brain Sciences* has a broad readership. Questions concerning the origins of the human mind have occupied linguists, psychologists, neuroscientists, primatologists and hunter-gatherer anthropologists (target article, abstract) – not forgetting cultural evolutionists, geneticists and theologians. Not all disciplines are equally well-versed in the inferential pitfalls of archaeological data – taphonomy, underdetermination, equifinality, absent evidence (Will). **Kuleshova et al.** remind us that language evolution research is fundamentally interdisciplinary, and that evidence from contemporary foragers can help in calibrating our baseline assumptions about how language might (or might not) manifest in the material record. Present discussion may be useful to readers of other specialisations also.

Last, and relatedly, as **Will** highlights, perspectives from beyond the field (e.g., Harari, 2014) have given "distorted portrayals of human origins." I know, first-hand, how difficult it is to prevent such distortions; a recent co-authored paper explored hunting exclusively among contemporary humans (Venkataraman et al., 2024), yet a UK broadsheet newspaper called these "prehistoric societies" and ran the headline "Ancient man did most of the hunting after all" (Rhys, 2024, now corrected). Fully inoculating against misinterpretation is unfeasible, but there are steps that may limit it:

1) Many papers give caveated yet precise chronological boundaries or date-ranges for particular capacities (e.g., Backwell et al., 2018; Kelly et al., 2023; Paige & Perreault, 2024). These should be presented carefully, as they imply surety and are easy for non-experts to latch onto, leading to simplistic portrayals from science communicators. For instance, in a recent exploration of the origins of cumulative culture (Paige & Perreault, 2024), the authors clearly explain the inferential issues of taphonomy, but most press summaries emphasised only the date boundary (Putol, 2024; Russ, 2024; Timmer, 2024).
2) Works linking particular artefacts to particular capacities (Coolidge et al., 2016) or neurocognitive mechanisms (Stout, Chaminade, Apel, Shafti, & Faisal, 2021) are easy for popularisers, funders and even disciplinary outsiders to interpret as presence/absence acid tests for these capacities – even where this is not the intended interpretation. Researchers should explicitly address the role of negative evidence (Wallach, 2019) – what we could conclude were these artefacts absent. Where researchers make no inferences from absence, they should say so clearly. Where they do, they should ensure theories would be sound if applied to the ethnographic record.
3) We should be more hesitant to comment on cognitive capacity shifts (Coolidge et al., 2016; Gabora & Smith, 2019; Kelly et al., 2023; Paige & Perreault, 2024). These may often simply be inferentially inaccessible and, whatever their link to the material record, must always precede expression (Haidle, 2016; Hovers & Belfer-Cohen, 2006) by an undetermined interval. Indeed, questions concerning the social, environmental and ecological contexts of behavioural and technological change (**Sterelny**; **Ben-Oren et al.**; **Di Paolo et al.**) are often more interesting and accessible to inquiry (e.g., Blessing, Conard, & Bader, 2023; Hovers & Belfer-Cohen, 2006, 2024; Hussain

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& Will, 2021; Miller & Wang, 2022; Shea, 2011). Many studies which do explore capacity shifts present findings (Backwell et al., 2018; Kelly et al., 2023; Paige & Perreault, 2024) that would be similarly exciting were these discussions omitted.

R6. Conclusion: Bridging theories over troubled water

Although the data brought to bear in this discussion complicate the link between material culture and cognition, it would be wrong to "lay down arms." As **Will** emphasises, Archaeology definitively "retains a central role to study the behavioral and cognitive evolution" of our lineage. Indeed, the field has never been stronger. It dominates the pages of leading journals with paradigm-altering new discoveries (Barham et al., 2023; Détroit et al., 2019; Oktaviana et al., 2024). It continues to push forward our understanding of the past with novel inductive methods (Fajardo et al., 2023; Kelly et al., 2023; Paige & Perreault, 2024; Stout & Hecht, 2023). It continues to reflexively examine and re-examine its own assumptions and biases (Hovers & Belfer-Cohen, 2006; Kissel & Fuentes, 2021; Liu & Stout, 2023; McBrearty & Brooks, 2000; Meneganzin & Currie, 2022; Shea, 2011; Wynn et al., 2021) and to write and re-write the history of our lineage (Blessing, 2023; McBrearty, 2013; Scerri & Will, 2023). It self-corrects, updating models in light of new evidence (Hardy et al., 2020; McBrearty & Stringer, 2007; Meneganzin & Killin, 2024), yet keeping grander claims in check (Foecke et al., 2024). It reaches across disciplinary boundaries to synthesise new insights and generate new theory (Ben-Oren et al., 2023a, 2023b; Crema, Bortolini, & Lake, 2024; Lane, 2014; Liu & Stout, 2023; Moreau, 2020; Padilla-Iglesias et al., 2024; Page & French, 2020; Paige & Perreault, 2024; Sterelny, 2019; Tennie, Premo, Braun, & McPherron, 2017). This is a field in rude health.

Neither, however, should researchers of any specialism look away – or dismiss the concerns raised here as unrepresentative, irrelevant or obsolete. We must acknowledge that our work is situated in a research tradition that has, historically, overemphasised its own achievements (Blurton Jones & Konner, 1989) and de-emphasised those of others – both of our own species (**Milks**) and beyond (**Blessing**; **Falk**). We should be aware that our conceptions of humanity are circumscribed by the idiosyncratic cultural contexts in which we live; a challenge that other behavioural sciences are only now tackling (Broesch et al., 2020; Gurven, 2018; Henrich et al., 2010). Even when alive to both these issues, they may still sometimes tacitly but concretely curtail our frames of reference and distort our epistemology. Vigilance is always warranted and, though criticism is fatiguing, sometimes paralysing, it will never be prudent to move beyond it. Instead we must continue incorporating it into our models and theories.

Although, to illustrate this discussion, it is necessary to highlight particular examples, the purpose is not censure, nor a commentary on the broader contributions of these researchers, which are often outsized. Nor is the target article's aim to retread past pessimism ("We cannot know. Tough luck!," Lewontin, 1998, p. 130). Instead, it aims to share relevant insights gained through direct engagement with hunter-gatherers themselves: That those who have been described as primitive (Bagshawe, 1925; Noetling, 1911) or stuck in the past (discussed in Solway et al., 1990) are modern and complex; that these rich social, linguistic and cognitive worlds are ephemeral – realised in speech, thought, play and a panoply of other activities that evaporate, leaving no enduring mark. **Bedetti & Allen** caution that extending these insights to the deep past is romanticism. Perhaps so. Yet I hope this discussion provides a solid material basis for reconsidering, even modestly, how we reason about those who do not set their humanity in stone.

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