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What Stimulated Rapid, Cumulative Innovation After 100,000 Years Ago?

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Abstract

Imagination and innovation are likely stimulated through the intersection of brain power, motor skill and social need. Through time, escalating creativity may have influenced cognition and social interactions, creating a feedback situation that also implicated demography. Such reciprocal interactions between technology, cognition and society may have motivated the accumulation of innovations that are particularly visible in the archaeological record after 100,000 years ago (not as a revolution, but incrementally). Raw materials also played a role because they are not passive; intense interaction with objects reflexively stimulates human imagination and creativity. Archaeological evidence for material culture items that appear to embody imagination is present before the appearance of *Homo sapiens*. The implication is that imagination is not the sole preserve of people like us; nonetheless, *H. sapiens* took imaginative expressions to new heights after about 100,000 years ago. Perforated and ochre-covered marine shells were found in early modern human burials and living sites and thereafter more material culture items convey imagination. Shell beads were strung to form a variety of patterns, and engraved ostrich eggshells, engraved ochre, worked bone and hundreds of pieces of utilised ochre have been widely found. Innovation, imagination and complex cognition are also conveyed in the manufacture of everyday objects used for subsistence activities.

Keywords Imagination · Reflexivity · Cognition · Social interaction · Technology · Stone Age/Palaeolithic

Introduction

By 100,000 years (100 ka) ago, evidence for innovative material culture multiplies, and the modes of innovation become progressively diverse thereafter, implying amplified

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use of imagination by skilled workers. The creative outputs evinced in the archaeological record that will be presented shortly have their origin in imagination, which is central to human life (Bloch 2013), and is a prerequisite for innovation. Imagination is defined by Agnati *et al.* (2013) as the formation of mental images of objects or situations not present, nor previously experienced. It allows prediction of action through a 'simulation' process, and it is also the ability to combine and transform mental images in original ways, thereby enabling creative thought and action (Agnati *et al.* 2013). Escalation of novel behaviour at 100 ka ago cannot be linked to the origin of *Homo sapiens* since earlier-known skeletal remains of *H. sapiens* date to about 300 ka ago in Africa (Hublin *et al.* 2017). Furthermore, as I shall shortly demonstrate, some novelties are not species specific and *Homo sapiens* cannot be given credit for all of them. Why, then, does evidence for creativity intensify after about 100 ka ago? This intriguing question has been explained in a number of ways by others; for example, (1) it is the outcome of change within the human brain, (2) it was stimulated reflexively by increasing technological skill, (3) it arises from social need and (4) it is a response to demographic pressures. I shall briefly discuss these potential stimuli for material culture change and shall then introduce archaeological evidence for innovative behaviour and its evolution through time.

Changes with the Human Brain

Cranial size reached modern proportions before the period under discussion (Bruner in prep) so encephalisation is not a factor to consider here. Nonetheless, changes in cranial shape imply qualitative changes within the brain. At about 100 ka ago, the brain of *Homo sapiens* became markedly globular, and there was parietal bulging in *H. sapiens* and also *H. neanderthalensis*, alongside apparent improvements in visuospatial abilities (Bruner in prep). Parietal cortex is principally implicated in functions affecting interactions between the brain, body and environment (Bruner in prep) so it must be important for innovation. Yet, if changes within the brain were responsible for increased imagination and innovation through time, then an essential contributory factor must have been neural connectivity between components of the brain. Twenty-five years ago, in a seminal archaeological study, Mithen (1996) suggested that such connectivity was an important enabler of 'modern' behaviour. Before moving forward, it is first necessary to investigate which regions of the brain activate imagination and creativity. Secondly, we must ask how changes within the brain might have enabled innovation.

Imagination relies on, and builds on memory, and while these seem ostensibly distinct cognitive functions of the brain, this is not the case because links are apparent in their processes (Mullally and Maguire 2014). The hippocampus is critical for mental recall, particularly in the case of spatial memory (Corballis 2017), as well as for imagining or recollecting scenes (and some aspects of social behaviour, to be discussed shortly). The ventromedial prefrontal cortex is also required for scene construction (Barry *et al.* 2019), and it, furthermore, enables people to predict likely events or states so that this ability can be used to shape decisions about future action (Benoit *et al.* 2014). Magnetoencephalography on human volunteers confirms that the ventromedial prefrontal cortex selects the elements for an imagined scene, whereas the hippocampus constructs the imagery (Barry *et al.* 2019). Brain imaging demonstrates, further, that the hippocampus is activated in other circumstances involving memory and imagination, such as when people are asked to imagine fictitious events (Corballis 2017). Since no brain region can undertake a cognitive task alone, the hippocampus often teams up with the angular gyrus to enable divergent thought, memory of past events and the imagining of future ones (Cabeza *et al.* 2020). Divergent thought is, of course, necessary for creative behaviour because it combines diverse information in novel ways (Cabeza *et al.* 2020).

Highly creative people have neural connectivity between many areas of the brain (Beaty *et al.* 2018); thus, the ease with which areas of the brain interact may be as relevant to creativity as the degree to which those areas are developed. The study by Beaty and colleagues may also imply that neurotransmitters have potential to influence imaginative and innovative behaviour. Chermahini and Hommel (2010) posit a link between creativity and the neurotransmitter dopamine, but the relationship is not straightforward. Higher dopamine levels do seem associated with greater cognitive flexibility, and this attribute could certainly promote innovative thought. Since both neural connectivity (Colclough *et al.* 2017) and dopaminergic neurotransmission (Kaminski *et al.* 2018) are partly heritable, a propensity for creativity can be inherited. This possibility has implications for successive generations of creative behaviour, thereby facilitating cumulative innovation.

Neural activity is, for Stout (2019), the driver behind actions that promote further neural activity and, in turn, this reflexivity changes the functional and anatomical configurations of brain connectivity. Thus, the first and second hypotheses cannot be entirely separated.

Reflexivity and Innovation

When people process material, neural connectivity is stimulated and developed between the angular gyrus and interparietal sulcus (Malafouris 2013). This interaction is important for archaeologists to reflect on because, when artefacts are made, the processed material is not passive and simply *acted upon*; humans engage and interact with it (Malafouris 2013). Consequently, there is reflexivity between technical actions and responses in the brain; thus, making material culture items may have helped to shape changes in the brain (Malafouris 2008). Malafouris (in prep.) claims that humans evolve through their creative engagement with the material world. The comment by Roberts (2016) that the human brain is in a state of "constant becoming" is consistent with this premise. Hutchins (2010) rationalises further that action, including gesture, is part of concept-forming process. The borders between perception, action, and cognition are porous according to Seitz (2000), who explains that thought is an embodied activity and that motor aptitudes cannot be separated from intellectual competencies. The reason why such a conceptual separation is sometimes thought to exist is because technical expertise is first and foremost nonverbal and is consequently undervalued as a form of thinking (Wynn *et al.* 2017). The term 'expert performance' or 'expertise' was developed by cognitive psychologists to describe the type of thought processes that experts use in their fields (Herzlinger *et al.* 2017), and it can be readily applied to the types of technology observed in the deep past. Attributes of expert cognition include rapid problem assessment, accurate performance, an ability to shift attention between components of a task without losing track of the steps required, fast learning of new procedures and flexible reactions when difficulties appear during a task (Herzlinger *et al.* 2017). Expert cognition does not require or imply technical innovation, or even working memory, and stone knapping can be part of an expert cognitive system. Functional magnetic resonance imaging (fMRI) detects brain activation when humans create or think about using tools (Stout *et al.* 2011), so it is possible to identify those parts of the brain responsible for such activities. Since the human parietal cortex controls interactions between the brain, body and environment, developments in this region of the brain can be expected to affect technology such as stone tool manufacture (Bruner in prep).

Innovation and Social Need

The parietal area not only influences technology, but is also responsible for social interactions, so developmental changes in this part of the brain are likely to accompany changes in social systems (Bruner in prep). The ventral hippocampus and medial prefrontal cortex are also key areas of the brain for controlling social behaviour (Sun *et al.* 2020). Functional magnetic resonance imaging by Stout et al. (2011) provides useful support for the concept of links between the brain and technical and social activity. The imaging implies a relationship between motor activities, social cognition and cumulative culture. The term 'technological niche' is used to underline the importance of object modification and its use for neurological evolution (Stout and Hecht 2017). Thus, the first three hypotheses mooted at the beginning of the paper can immediately be linked; indeed, it is clear that social need can never be entirely isolated from technical and intellectual abilities. This makes sense because technological developments, while dependent on intellectual capability, also cannot be isolated from social need, and it is likely that social demand always preceded the innovation that subsequently served it.

The role of imagination extends well beyond the technical innovation discussed in the previous section because, moreover, our minds create and embrace social life and our relationships with others (Gamble *et al.* 2014). Imagination enables us to classify not only objects in the natural world, but also people within our social milieu. Gamble *et al.* (2014) suggest that real or imagined kinship relationships are not unlike the taxonomies that people generate for edible or medicinal plants, or categories of rocks and minerals. Concepts of real or imagined kinship enable people to conceptualise afterlives for their dead relatives, and these can include ancestral roles that influence the lives of the living. The idea that a person exists after death as part of the social system of the living (Gamble *et al.* 2014) has relevance when we look at the early evidence for burial (to be examined shortly). Such imaginative capacity articulates with a theory of mind, and we can readily accredit early *Homo sapiens* with this ability (Gamble *et al.* 2014). The aptitude would also have enabled people to migrate into the unknown (Gamble *et al.* 2014), and to perceive analogies between tried and tested resources and unfamiliar ones in new territory.

Innovation and Demography

Social behaviour and demography are intertwined. New types of social conduct are sometimes linked to demographic and environmental change and these, in turn, may give rise to innovations (Ash and Gallup 2007; Powell *et al.* 2009; Mackay *et al.* 2014). Demographic shifts can be used to explain some material culture variability because innovation tends to be inhibited in small populations, whereas the skill base increases when populations grow (Powell *et al.* 2009), and therefore more items of material culture are produced. As mentioned earlier, technical thought is almost always embedded in a social context, with its own set of cognitive considerations, but it is also clear that demographic issues are influential. Dunbar's social brain hypothesis (for example, Dunbar and Shultz 2007) is pertinent here. In essence, this predicts that the exigencies of living in large, complex groups selected for large brains. Brain size change is not germane in the period under discussion, but other components and functions of the brain are important. Humans live in highly social groups and in order to navigate social space in a way that avoids conflict, people need superior inhibitory control (Green and Spikins 2020). 'Response inhibition' (*i.e.* delayed gratification) is one executive function of the brain, together with planning and strategising, decision-making, and organising and sequencing events that are necessary for the complex cognition that we associate with people nowadays (Coolidge 2019, 406–407). Response inhibition may have developed early for it would have been required by people transporting food from the field to a home base for sharing.

Hunter-gatherer social structure is characterised by nuclear family units and fluid band membership so that there is extensive between-camp mobility (Migliano *et al.* 2020). Migliano *et al.* (2020) suggest that multilevel social structuring enables the coexistence of multiple traditions in different parts of the network so that no individual is aware of the full range of innovations within the entire network. As bands or individuals move and meet, cultural recombination may take place (Migliano *et al.* 2020). Relationships involving ritual increase the rates of interaction between people more than kinship (Hill *et al.* 2014). Cumulative culture is partly due to the fact that humans observe many individuals in a lifetime, and are consequently likely to meet at least one that has created a superior innovation worthy of imitation (Hill *et al.* 2014). Hunter-gatherers invariably practice aggregation and dispersal as part of their mobile, fluid demography and flexible social structure and during aggregation phases when group size is relatively large, people are especially likely to observe innovations that are worth copying (Belfer-Cohen and Hovers 2020).

I move now to discuss the relevance of this theoretical backdrop for the interpretation of archaeological evidence. The brief synopsis of four hypotheses that explain circumstances required for the stimulation of imagination and innovation intimates that no single explanation suffices; the necessary conditions most likely depend on the intersection of the brain, motor skill, demography and social need. Through time, escalating imagination, creativity and innovation may have infused cognition, demography and social interactions and created a feedback situation. The process would have been incremental. Indeed, no revolution occurred in the Stone Age; arguments against this are well-described elsewhere (McBrearty and Brooks 2000; Roberts 2016).

The Dawn of Imagination?

Imagination is exhibited early in the archaeological record, though examples are sporadic and sometimes controversial. A red jaspilite pebble with natural markings resembling a human face was brought into Makapan, South Africa, three million years ago, presumably by *Australopithecus africanus*. Is it possible that *Australopithecines* were capable of pareidolia? Humans have specialised cognitive and neural mechanisms reserved for perceiving faces—that part of the brain responsible for this ability is the fusiform face area (Kanwisher and Yovel 2006). We have no idea, of course, whether the *Australopithecine* brain had a fusiform face area, but since some modern monkeys are able to recognise depictions of faces (Kanwisher and Yovel 2006),we cannot rule out pareidolia in *Australopithecines*. A considerable amount of time and distance separates the Makapan pebble from a similar archaeological curiosity in Israel. The Lower Palaeolithic site of Berekhet Ram yielded a rock that appears to have been humanly modified about 300,000 years (300 ka) ago to resemble an informal figurine of a female (d'Errico and Nowell 2000; Haidle *et al*. in prep). Imagination seems even more securely implicated in the act of a handaxe maker at about 400 ka ago in West Tofts, England. The knapper selected a rock with a fossil shell embedded in it, and the rare inclusion may have been more valued than the tool's cutting edge (Wynn and Berlant 2019, 291). Aesthetics obviously played a role in Acheulean handaxe technology, possibly for social reasons (Wynn and Berlant 2019). The fMRI method, tested on modern volunteers that included both proficient and naïve stone knappers, demonstrates that important components of human-like cognition were already established at the time that Acheulean technology was created (Stout *et al.* 2011). Archaeological data add further evidence: at the site of Gesher Benot Ya'aqov (GBY), Israel, dated 780 ka ago, the manufacture of Acheulean cleavers involved careful control of convex surfaces; thus, planning was essential for the process. The GBY knappers had a clear concept of requirements for the finished tool and their knapping technology reflects expert cognition (Herzlinger *et al.* 2017). During cleaver production, the knappers aimed to thin the bulb of percussion, reduce mass and create a smooth dorsal surface at the distal end of the tool. Attention had to be shifted from one knapping task to the other and back again, and this implicated the 'cognitive control' components of working memory (Herzlinger *et al.* 2017).

After almost a million years of conservative stasis, technological transformations increased between about 350 and 300 ka ago. European lithic assemblages of the time included expanded and diverse débitage methodology and greater standardisation of end products, and these changes appear to mark the shift from the Lower to the Middle Palaeolithic (Fontana *et al.* 2013). Sangoan core-axes were hafted a quarter of a million years ago at Sai Island, Sudan (Rots and Van Peer 2006), but elsewhere in Africa lithic technology was already recognisable as 'classic' Middle Stone Age. Ethiopian stone points that could have been parts of hafted weapons or implements are dated older than 300 ka ago (Sahle *et al.* 2013). Sites dated close to 300 ka ago in the Olorgesaile area of Kenya, East Africa, yielded Middle Stone Age technology with points, rocks transported from up to 50 km away and iron-rich rocks that were probably collected for their red pigment (Brooks *et al.* 2018). K4 bedded tuffs of the Kapthurin Formation, Kenya, also yielded small bifacial points, securely dated to 285–235 ka, and thought to have been hafted weapon inserts (McBrearty and Tryon 2006). Even earlier unifacial points are reported from Kathu Pan, South Africa (Wilkins *et al.* 2012), but the chronology seems not as secure as that in East Africa. If the 500 ka old Kathu Pan context can be convincingly demonstrated, then composite tool technology commonly attributed to the Middle Stone Age appeared well before the earliest *Homo sapiens* fossils. Composite tools such as spears hafted with stone points for tips are considered to be markers of complex cognition because their manufacture makes demands on constructive memory (Ambrose 2010). Composite tool manufacture requires multi-component assembly, and the imagination and planning skills required (Barham 2013) may have progressed together with developments in the brain's anterior frontal lobe, perhaps at around 300 ka ago (Ambrose 2010). Hafting technology may arguably have been one of the earliest innovations that appeared in Africa before *Homo sapiens* was established on the landscape (Ambrose 2010; Wilkins *et al.* 2012; Barham 2013; Brooks *et al.* 2018).

As mentioned above, ochre is an early inclusion in Old World sites; we do not know whether this was because the salient red colour caught the imagination of hominins or whether the material's functional roles had already been discovered. Ochre is a ferruginous rock containing iron oxide such as haematite (α-Fe2O3), or hydrated iron oxyhydroxide such as goethite (α-FeOOH) (Schwertmann and Cornell 1991). Neanderthals used a liquid form of ochre for unknown purposes at Maastricht-Belvédère in the Netherlands by 250–200 ka ago (Roebroeks *et al.* 2012). Worked ochre was found at GnJh-15, Kenya (285 ka) (McBrearty 2001), in the 250 ka Lupemban Industry at Twin Rivers, Zambia (Clark and Brown 2001; Barham 2002), in the Sangoan Industry of Sai Island, North Africa, by 200 ka ago (van Peer *et al.* 2003, 2004), and it was found even earlier in the Fauresmith Industry of Kathu Pan, South Africa, (Wilkins and Chazan 2012; Watts *et al.* 2016).

Between a million and 300 ka ago, the morphology of several relatively large-brained African fossil specimens, displaying high, vertical-sided brain cases, matches neither *Homo ergaster* nor *Homo sapiens*. The specimens are termed archaic *Homo sapiens* (Clarke 2012) and such fossil crania were associated with Sangoan lithics (that include large, pick-like bifacial tools) at Lake Eyasi, Tanzania (Mehlman 1987). By approximately 300 ka ago, fossils of *Homo sapiens* emerged at several sites in Africa, in both the north and south of the continent (for a review, see Grine 2016). *Homo sapiens* fossil remains date to about 315 ka ago at Jebel Irhoud in North Africa (Hublin *et al.* 2017). The South African Florisbad cranium, which displays both modern and archaic features, but is thought to be closely related to *Homo sapiens* (Clarke, 1985, 2012), is dated to 259 ± 35 ka ago (Grün *et al.* 1996). Similar *Homo sapiens* crania were found at Guomde, Kenya, dated 270 ka ago (Bräuer 2001). Recent genetic and palaeoanthropological data imply that there was a multiregional origin for *Homo sapiens* in Africa (Schlebusch and Jakobsson 2018). The initial part of the modern human story belongs exclusively to Africa, but some genetic studies propose advanced expansions from Africa to adjacent continents by 220 ky ago (Posth *et al.* 2017). Skeletal remains from Misliya Cave, Israel, dated 194 to 177 ky ago support this proposal and imply that *Homo sapiens* dispersed from Africa *via* Sinai before using the southern route (Hershkovitz *et al.* 2018). The later phase of human expansions at the start of the last interglacial (after about 130 ka ago) is better known. Jebel Faya in Arabia was occupied by 125 ky ago, and this supports crossing of the Bab al-Mandab by *Homo sapiens* before the last interglacial onset when rising sea levels widened the strait (Armitage *et al.* 2011).

We should be cautious about assuming that all Middle Stone Age sites were occupied by *Homo sapiens* because the African story has grown more complex since the discovery that *Homo naledi* lived more or less contemporaneously with early *Homo* *sapiens* (Dirks *et al.* 2015; Irish *et al.* 2018). This caution must, of course, be extended beyond Africa where the fossil and genetic records demonstrate contemporaneity and interbreeding between Neanderthals, *Homo sapiens* and Denisovans in, for example, Eurasia (Scerri *et al.* 2019), and Neanderthals and Denisovans at Denisova Cave, Russia, which was first occupied about 300 ka ago (Morley *et al.* 2019). Fossil and genetic findings in the last few years have metaphorically shaken the roots of the evolutionary tree. We can no longer be certain of the authorship of material culture items.

The early use of bone as a raw material is an example of regional diversification that may also have been influenced by variability in the technological niches occupied by separate hominin species. By 1.8 million years ago in Africa, bone was already part of toolkits (Brain and Shipman 1993; Backwell and d'Errico 2005). Different bone-working techniques were exploited in East and South Africa. Bone was flaked at Olduvai, whereas bone from Members 3–1, Swartkrans, South Africa, has grinding striations and seems to have been used for extracting termites from their mounds (Backwell and d'Errico 2005), so production and use varied regionally. This is also evident in the parts of bone chosen: in South Africa, weathered long bone shafts and horn cores were used, while East African hominins worked with fresh bone from large animals (Backwell and d'Errico 2005).

Within the last million years, the occasional use of fire can be attributed to several hominin types, both in and out of Africa. Fire was a prerequisite for much of the technology later used by *Homo sapiens*, but some of its advantages were clearly understood by other hominins. Fire prompts imagination in many ways and is a social focus as well as a technological aid. The control, curation and ability to create fire were critical developments. We probably cannot speak of pyrotechnology *per se* until hominins could generate fire at will. Surprisingly, archaeological evidence for habitual use of fire is uncommon until relatively late. The million-year-old hearth in the deep recesses of Wonderwerk, South Africa (Berna *et al.* 2012), or the reddened earth and burnt stone at open-air-site Koobi Fora, Kenya (Cutts *et al.* 2019), was almost certainly the result of short-term curation of coals after expedient collection of wildfire. These Earlier Stone Age sites lack the evidence for stacked combustion features of the type seen in many Middle Stone Age sites. Charred and calcined bone and heated chert were excavated from 800-ka-old layers in the Spanish cave, Cueva Negra (Walker *et al.* 2016). The use of fire at GBY 780 ka ago (Alperson-Afil 2008) might also have been expedient, something that seems less likely at Qesem Cave, Israel, where a central hearth was lit and possibly curated more than 300 ka ago (Stiner *et al.* 2011; Barkai *et al.* 2017). Wildfire in nature is generally caused by lightning, and Sandgathe (2017) points to a strong correlation between interglacials (when lightning is common) and fire frequency in European archaeological sites, and he argues that this rather counter-intuitive situation (because we expect more fires in cold periods) could imply hominin dependence on natural fire sources up until the Late Pleistocene. Furthermore, Roebroeks and Villa (2011) show that there is no evidence that fire was necessary for the colonisation of Europe, notwithstanding the uninviting conditions of glacial episodes. Nonetheless, as mentioned earlier, the advantages of fire were known by hominins other than *Homo sapiens*. Evidence for fire used by Denisovans was present in Denisova Cave more than 200 ka ago (Morley *et al.* 2019) and by 176 ka ago at Bruniquel Cave, France, Neanderthals were not only using fire in the dark, deep cavern, but were also creating circles there from speleothem (Stade and Gamble 2019, 325).

Imagination and Innovations After 100,000 Years Ago

By the time that we recognise pyrotechnology involving processes like heat treatment of rocks and minerals, we can probably assume that people could reproduce fire at will, though we have as yet no secure evidence for fire-lighting techniques in the past. The use of rocks and minerals for strike-a-light fire-starting is most likely (Sorensen *et al.* 2014), but the technique is difficult to recognise in sites where the knapping of rocks for tool-making is prevalent. Heat treatment of rocks is suspected at Pinnacle Point from about 164 ka ago (Brown *et al.* 2009), but at present there is no other evidence for such technology before about 100 ka ago. Heat treatment facilitates pressure flaking (Mourre *et al.* 2010) and it was clearly used by 70 ka ago in southern Africa, for example at sites like Blombos (Mourre *et al.* 2010) and Diepkloof (Schmidt *et al.* 2015), and by 65 ka ago at Klipdrift (Delagnes *et al.* 2016).

Not only rocks for knapping, but also ochre pieces were deliberately heated in the past. This may have been done to transform yellow, brown or light red pieces to brilliant red, but texture also changes after heating. Watts (2010) suggests that Pinnacle Point ochre may have been roasted to alter its colour by about 100 ka ago. At Qafzeh, Israel, two ochre lumps, dated to between 100 and 92 ka ago, were probably heated to transform their colour from yellow to red (Hovers *et al.* 2003). Heat treatment was identified by thermoluminescence (Godfrey-Smith and Ilani 2004). The Qafzeh red ochre was found with human burials where it probably served a symbolic role (Hovers *et al.* 2003).

Ochre, whether heated or not, seems to have been extensively employed in the past, not only by *Homo sapiens*, but, as mentioned in the previous section, by other hominins, too. Apart from these early examples of ochre exploitation, it was also excavated from the late MIS 6 layer at Wonderkrater, South Africa (Backwell *et al.* 2014). Ochre pieces found in archaeological sites are frequently unworked manuports, but sometimes ochre was ground or scraped, apparently to obtain coloured powder.

While red ochre exploitation may sometimes have been linked to imagination that resulted in symbolic action, it seems to have had technical uses too. We do not know whether the early paint-like substances were symbolic media, whether they had more prosaic functions or whether they served both purposes. Either way, the technology demonstrates considerable imagination as well as technical skill. (Malafouris 2008). Ochre-rich paint was found in a *Haliotis* shell in Blombos Cave, South Africa, with an age of 100 ka (Henshilwood *et al.* 2011). By about 49 ka ago, paint recipes were so advanced that a type of tempera (a mixture of casein and ochre powder) had been invented and used at Sibudu (Villa *et al.* 2015).Ochre powder is useful for many tasks; amongst them, it can be used as a loading agent in adhesive manufacture. In the Middle Stone Age, compound adhesives were used to attach stone tips to handles or shafts (for example, Gibson *et al.* 2004; Lombard 2006, 2007; Wojcieszak and Wadley 2018). A flaked tool from Sodmein (pre-Middle Stone Age) has ochre in association with potential resin residues (Rots *et al.* 2011); thus, the use of adhesives may be ancient. Zipkin *et al.* (2014) have demonstrated that ground quartz, like ochre, can act as a reliable loading agent, and other experimental replications show that adhesive ingredients can also include plant gum/resin and fat or wax (for example, Wadley *et al.* 2009). Heat from fire was possibly an essential part of manufacturing adhesive (Cnuts *et al.* 2017). It seems that a variety of fixative recipes may have been used in the Middle

Stone Age and even simple glue, such as resin from *Podocarpus* (yellowwood), was sometimes used for hafting Middle Stone Age tools at sites like Diepkloof (Charrié-Duhaut *et al.* 2013). Bitumen was a single-component fixative paste used in the Middle Palaeolithic of Europe (for example, Cârciumaru *et al.* 2012) and Syria (for example, Boëda *et al.* 1996). Adhesive production is a candidate for being a recursive process (Welshon 2019, 70), so the innovation is an important cognitive marker as well as an enabler of composite technology. The process involves, amongst other executive functions, pre-planning, multi-tasking, and response inhibition (Wadley 2010). Cognitive development is seen to become even more complex at the stage when composite tools begin to be used symbiotically—for instance in bow and arrow sets where a great many manufacturing steps are implicated (Lombard and Haidle 2012). While bow and arrow are most commonly known in the African Later Stone Age, it is possible that bone arrows were used at Sibudu, South Africa, by about 62 ka ago in the Howiesons Poort Industry. This new hunting technique is likely to have had social implications because it enables individual as opposed to group hunting. Thus, bow and arrow hunting may have arisen as a response to group fluidity, that is, the fragmentation of groups into dispersal camps.

The Sibudu bone point was preceded by the invention of a profusion of bone tool types that emerged from the beginning of the Middle Palaeolithic/Middle Stone Age and multiplied significantly after about 100 ka ago. In early Middle Palaeolithic occupations of Gran Dolina, Spain, bone tools were made by percussion, and bone hammers were used (as they were in several European Middle Palaeolithic sites) (Rosell *et al.* 2011). Early Middle Stone Age layers in Kabwe Cave, Zambia, yielded two spatula-like tools and a polished piece that looks like a bone point (Barham *et al.* 2002). Middle Stone Age craftspeople favoured ribs for several types of artefacts. A bone knife made from a rib was dated about 90 ka ago at Dar es-Soltan 1, Morocco, and similar worked rib bones from Aterian assemblages of El Mnasra cave are dated about 111 ka ago (Bouzouggar *et al.* 2018). Widely separated sites (Apollo 11, Klasies River and Sibudu) have notched or serrated rib fragments of uncertain purpose (Vogelsang 1998; Singer and Wymer 1982; Wadley 2015). Barbed bone points that look extraordinarily like harpoons were found at the 82-ka-old open-air site at Katanda, Zaire (Yellen *et al.* 1995). The collection of Blombos bone artefacts from the 80- and 72-ka layers includes awls, a bone retoucher, and large bone points, possibly spearheads, that were scraped and polished (Henshilwood *et al.* 2001; d'Errico and Henshilwood 2007). Sibudu has a rich bone tool industry, beginning at 77 ka ago, with a wide variety of tool types including retouchers, scrapers and pointed tools (d'Errico *et al.* 2012a). McBrearty and Brooks (2000: 503) link bone working and the development of projectile technology. Certainly, there are some indications that projectile technology has its origins in the Middle Stone Age (for example, Sahle *et al.* 2013), indeed that a variety of hunting techniques were exploited then. Hunting was not, however, the only diversified economic strategy of the time; both *Homo sapiens* and Neanderthals included more systematic use of marine resources from MIS 6 onwards, in both Africa and Europe (Will *et al.* 2019). Although marine resources were exploited at Pinnacle Point by 164 ka ago (Marean *et al.* 2007), the marine component of Middle Stone Age diets was not extensive until about 100 ka ago in southern Africa. After about 130 ka ago, at the estimated start of relatively warm Marine Isotope Stage 5e, the multiplying economic possibilities and resultant food security opened new avenues for territorial expansion, group fluidity and demographic shifts. While environmental conditions may have prompted the change, ventures into the unknown by *Homo sapiens* would have been considerably aided by imagination, an analogical facility and, perhaps most importantly, social structures enabling group aggregation and dispersal.

Earlier changes in social behaviour are likely to have been responsible for the burial practices that seem to have originated at about 100 ka ago. Gamble *et al.* (2014) claim that burial is not so much about an ‘after-life’ as an ‘after-person’. Imagination enables people to think about their ancestors, and this ‘social imagination’ must have been present at the time that the first burials with grave goods appear. Burials without grave goods could, perhaps, be argued to represent disposal of corpses to keep predators away from a campsite. The earliest unambiguous burials date to about 100 ka ago at Skhul and Qafzeh in Israel, where marine shell beads (Bar-Yosef Mayer *et al.* 2009) and red ochre (d’Errico *et al.* 2010) appear to have served as grave goods placed with the bodies of the deceased. Several anatomically modern humans were buried in Qafzeh Cave and the adolescent, Qafzeh 11, was interred with fallow deer antlers on its chest, while Skhul V had the mandible of a wild boar placed in its hands (Belfer-Cohen and Hovers 1992). Pieces of worked ochre were associated with the skeletal remains at Qafzeh and they appear to have been used in the burial ritual (Hovers *et al.* 2003). No unequivocal burials of such antiquity have yet been found in Africa, but the Border Cave BC 3 infant skeleton buried with a perforated *Conus* seashell is thought to date to about 74 ka ago (d’Errico and Backwell 2016). More controversial are claims for much earlier interments of fossil hominins in the Spanish site, Sima de los Huesos (Egeland *et al.* 2018), and the *Homo naledi* remains in the Dinaledi Chamber, South Africa (Dirks *et al.* 2015; Irish *et al.* 2018). An array of statistical tests cluster the hominin skeletal assemblages from both sites with records of remains of scavenged corpses, leopard-consumed baboons and baboons that died naturally within a cave, yet the tests can also not emphatically refute potential deliberate interment (Egeland *et al.* 2018).

Other new types of social behaviour were adopted at about 100 ka ago and some imply that displaying group identity became important to *Homo sapiens*. Blombos engraved ochre, 100–72 ka ago (Henshilwood *et al.* 2002, 2009), is a slightly puzzling example because the engravings are small and, to our modern eyes, seem therefore to be ineffectual emblems. Klasies River Cave 1 has an MIS 5 layer (~ 100 to 85 ka) that yielded a fragmented ochre pebble with deliberate linear incisions (d’Errico *et al.* 2012b). The tradition is geographically widespread in South Africa and fan-shaped motifs were incised on some Sibudu 72-ka-old ochre pieces (Hodgskiss 2013). Klein Kliphuis produced a refitted piece of engraved ochre (Mackay and Welz 2008). The practice of engraving of geometric designs developed further within Howiesons Poort assemblages from about 65 ka ago in the southern part of South Africa. Engraved ostrich eggshell fragments and perforated eggshell openings from water bottles were recovered from Diepkloof’s Howiesons Poort (Parkington *et al.* 2005; Texier *et al.* 2010, 2013). Engraved eggshell occurs at Middle Stone Age sites other than Diepkloof, so the practice of marking water bottles is repeated on the landscape. This seems important if we wish to infer group identity from the emblems. The 65-ka-old assemblage at Klipdrift has 95 pieces of ostrich eggshell engraved with a variety of geometric motifs (Henshilwood *et al.* 2014). Farther north, some incised eggshell fragments in the MSA of Apollo 11, Namibia, have ochre on them (Wendt 1972; Vogelsang 1998: 84) and other fragments are water bottle openings (Wendt 1972; Vogelsang 1998: 75, 238).

Pecked water bottle openings were also found at Pockenbank, Namibia (Wendt 1972; Vogelsang 1998:236). Eggshell was not used for bead-making until much later in the Middle Stone Age. Mumba, Tanzania, may have the earliest examples at about 52 ka ago (Barham and Mitchell 2008: 271), and beads from Magubike Rockshelter, also in Tanzania, have ages of about 50 ka (Miller and Willoughby 2014), while the Tanzanian rock shelter, Kisese II, has eggshell beads dated 46 ka ago (Tryon *et al.* 2018). The use of perforated seashells that were probably beads for ornaments commenced much earlier, around 100 ka ago in both North Africa and Israel. Their use entails technology such as drilling and the creation of cord for threading and possibly knotting (Vanhaeren *et al.* 2013). The oldest known shell beads (*Nassarius gibbosulus*) are ~ 100-ka-old and were recovered from Skuhl in Israel (Vanhaeren *et al.* 2006). Similarly aged *Glycymeris* bivalves from Qafzeh, Israel, were used as beads or pendants; some were reddened with ochre and had wear marks from being strung (Bar-Yosef Mayer *et al.* 2009). Moroccan and Algerian sites also yielded perforated *Nassarius* shells, some from layers dated about 108 ka ago (Jacobs *et al.* 2012). The Grotte des Pigeons (Taforalt) beads are about 82 ka old (Bouzouggar *et al.* 2007) and several other North African sites have yielded beads of similar age (d'Errico *et al.* 2009). Perforated marine shells were not only grave goods; they seem to have played other social roles. The Blombos beads (Henshilwood *et al.* 2004) were possibly strung as ornaments, and/or they were stitched to clothing (Vanhaeren *et al.* 2013). Imaginative, stylistic change through time in the way that they were strung is implied by the wear patterns on the bead perforations. Early in the Still Bay occupations, shells were strung in alternate dorsal and ventral patterns, whereas a more recent style had beads tied dorsally (Vanhaeren *et al.* 2013). Shell beads also occur in Sibudu 72 ka ago (d'Errico *et al.* 2008; Vanhaeren *et al.* 2019), so again there is an established behavioural pattern that was geographically widespread in southern Africa.

Discussion and Conclusions

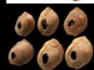
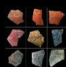
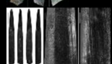
Notwithstanding some rare glimpses of unique behaviour that may have been motivated by a form of aesthetic appreciation, the Earlier Stone Age/Early Palaeolithic seems technologically and behaviourally less innovative than the Middle Stone Age/Middle Palaeolithic. Relatively few innovations can be identified until after 300 ka ago, and material culture suggesting imagination is scarce. 'Expertise' was the principle cognitive system deployed in the day-to-day task of survival for most of the human narrative and this is visible through analysis of the archaeological record, in particular lithic technology. While hominin endeavour was technically impressive even before the advent of *H. sapiens*, we see few skills in the pre-100 ka ago record that could not easily be passed on through nonverbal observation from an expert to an apprentice. Indeed, the technology observed in this early period is aptly described by the term 'expert performance', which was explained earlier. A number of hypotheses have been forwarded to explain the comparative conservatism of this period. As mentioned in the introduction, Mithen (1996) attributed this behaviour to a lack of connectivity between parts of the brain. Another suggestion, by Davidson and Noble (1989), is that the absence of language accounts for the ostensible stasis of the Earlier Stone Age/Lower Palaeolithic, and that the selective advantage of language enabled the subsequent dominance of *Homo sapiens.* They call attention to observations by developmental psychologists that children must acquire competent language skills before imagery becomes part of their cognition (Davidson and Noble 1989). The hypothesis that language was so influential is compelling even though its origin remains undated, and even though the hominin record is now more complex than it was in 1989.

A few remarkable finds implying aesthetic appreciation predate the appearance of *Homo sapiens.* These were described previously, and summarised in Table 1; they may allude to the possibility that some form of imagination is not the sole preserve of people like us, but it could equally be argued that they are merely happenstance. Even after the advent of *H. sapiens* at about 300 ka ago, other actors shared the Old World stage, and they may also have been creative and imaginative. We still know little about the behaviour of Denisovans, and even less about *Homo naledi*, but we are better informed as regards Neanderthal lifeways. The current evidence reveals considerable overlap in Europe between the behaviour and technology of *H. sapiens* and Neanderthals in the Middle Palaeolithic. By about 300 ka ago, there is archaeological evidence for new technologies involving fire, iron-rich rocks and hafting, and these inventions provided the foundations for more sophisticated developments in subsequent millennia. Quite often the users and inventors are anonymous because of a lack of identifying evidence, yet the general assumption by archaeologists is that *H. sapiens* was the responsible party. Such confidence may occasionally be misplaced as is suggested by the quarter-of-a-million-year-old ochreous liquid recovered from the Neanderthal camp at Maastricht-Belvédère. While the Neanderthal skill base included this ancient use of ochre, evidence for the distillation of plant tar and hafting of stone tools is much later.

The advent of *H. sapiens* anatomy at about 300 ka ago was not immediately followed by an explosion of technological advances and innovations. In this sense, there is an apparent decoupling of the first fossil evidence for anatomically modern humans and material culture evidence for behaviour considered appropriate for them. Not only is there a substantial time lag between anatomical modernisation and innovative changes in material culture, but the evidence that we can recognise archaeologically arrived neither contemporaneously nor uniformly across the landscape, and certainly not in large numbers. There may, however, have been subtle yet important developments in the human brain, the import of which we are not yet fully cognisant. At about 100 ka ago, for example, the brain of *Homo sapiens* became markedly globular (Bruner, in prep) and although we do not know whether this morphological change also corresponded with changes in neurological wiring of the brain, we see that it coincided with the material culture developments described here, and we suspect social parallels. It was not until about 100 ka ago that considerable diversity of technology is manifested and that new forms of material culture with potential links to social behaviour convincingly make their appearance. In Africa, it is plain that Middle Stone Age innovations occur in widely separated regions from southern to North Africa. Furthermore, there appears to be increasing evidence for movements of populations within and out of Africa from about 100 ka ago; thus, demographic shifts involving not only migrations but also band fluidity may have stimulated innovation.

Although I have already described some relatively early signs of imaginative technological development between 300 ka and about 100 ka ago (Table 1), the proliferation of innovative material culture after 100 ka ago is striking. In particular, potential proxies for imagination and executive functions of the brain become more

Table 1 Approximate chronology for the appearance of selected innovations at some sites mentioned in the text. The time frame is not to scale

Age (approximate)	Site	Item	
3 Mya	Makapan	face-like pebble	
1 Mya	Wonderwerk, Koobi Fora	fire	
780 ka	Gesher Benot Ya'kov	fire	
400 ka	West Tofts	handaxe & fossil shell	
~300 ka	Berekhet Ram	modified slab	
~300 ka	Kapthurin, Olorgesaile, Kathu Pan	hafted stone points	
~300 – 200 ka	Kapthurin, Olorgesaile, Twin Rivers, Kathu Pan, Maastricht-Belvédère	worked ochre	
100 ka	Qafzeh, Skhul	burial with grave goods	
>100 – 65 ka ago	Pinnacle Point, Klasies, Diepkloof, Klipdrift	heat treatment silcrete	
>100 ka ago	Pinnacle Point, Qafzeh	heat treatment ochre	
100 ka	Blombos	paint	
100 ka	Blombos, Klasies	engraved ochre	
~80 ka	Blombos, Katanda, Dar es Soltan	large bone points or harpoons, bone knives	
100 - 72 ka	Blombos, Sibudu, Klasies, Taforalt & N. African sites	marine shell beads	
>77 ka	Sibudu	compound adhesive, engraved ochre	
65 ka	Diepkloof, Klipdrift, Apollo 11, Pockenbank	engraved eggshell	
62 ka	Sibudu	bone arrowheads	

discernible after about 100 ka ago and, from then onwards, the trajectory for innovation is steep. As established earlier, the 100-ka period is when we find persuasive evidence for the use of ornamentation, burial with grave goods, colouring materials, engraved geometric motifs, complex, diverse bone tools, composite lithic technologies enabled by novel fixative methods, expanded subsistence strategies to include extensive marine exploitation and group mobility. Some of the novelties, like burial practices with grave goods, have clear social correlates and they reveal ingenious ways of thinking about inter-related roles of the living and the dead. Social need possibly more than technological requirement drove the Old World developments described here.

Evidence for imagination and highly developed technology can be used to imply complex cognition and brains with neural connectivity like ours, as well as highly developed social networks that were perhaps generated by demographic shifts that intensified at about 100 ka ago. Humans have consistently expanded their ranges within and out-of-Africa, probably more intensively in the last 100 ka ago than before (Scerri *et al.* 2019). Yet we can garner additional information from the archaeological evidence presented here. Since material culture is not passive, manipulation of raw materials to produce novel material culture items stimulates the brain to innovate further. Reflexivity between technology and cognition made humans smarter and more creative through time. In turn, this seems to have set in motion a feedback cycle of novel production that may have given rise to the escalation of inventions after 100 ka ago. This acceleration may have been encouraged by the reflexive relationship between brains, technology and social rewards that derive from innovation. These may have stimulated not only neural connectivity, but also dopaminergic neurotransmission and executive functions of the brain. Such heritable traits as executive functions (Coolidge *et al.* 2000) would, in turn, have privileged upsurges of creativity. Few things illustrate the process more convincingly than the surge in technology over the last 50 years. Indeed the process of innovating has accelerated to such an extent that artificial intelligence may guide the imagination of the future.

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Compliance with Ethical Standards

Conflict of Interest The author declares that she has no conflict of interest.

References

Agnati, L. F., Guidolin, D., Battistin, L., Pagnoni, G., & Fuxe, K. (2013). The neurobiology of imagination: possible role of interaction-dominant dynamics and default mode network. *Frontiers of Psychology*, 24 May 2013 | https://doi.org/10.3389/fpsyg.2013.00296.

Alperson-Afil, N. (2008). Continual fire-making by hominins at Gesher Benot Ya'aqov, Israel. *Quaternary Science Reviews, 27*(17-18), 1733–1739.

Ambrose, S. H. (2010). Coevolution of composite-tool technology, constructive memory, and language implications for the evolution of modern human behavior. *Current Anthropology*, 51 (Supplement 1), S135–S147.

Armitage, S. J., Jasim, S. A., Marks, A. E., Parker, A. G., Usik, V. I., & Uerpmann, H.-P. (2011). The southern route "out of Africa": evidence for an early expansion of modern humans into Arabia. *Science, 331*(6016), 453–456.

Ash, J., & Gallup, G. G. (2007). Paleoclimatic variation and brain expansion during human evolution. *Human Nature, 18*(2), 109–124.

Backwell, L., & d'Errico, F. (2005). The origin of bone tool technology and the identification of early hominid cultural traditions. In F. d'Errico & L. Backwell (Eds.), *From tools to symbols: From early hominids to modern humans* (pp. 238–275). Johannesburg: Witwatersrand University Press.

Backwell, L., McCarthy, T. S., Wadley, L., Henderson, Z., Steininger, C. M., de Klerk, B., et al. (2014). Multiproxy record of late Quaternary climate change and Middle Stone Age human occupation at Wonderkrater, South Africa. *Quaternary Science Reviews, 99*, 42–59.

Barham, L. S. (2002). Backed tools in Middle Pleistocene Central Africa and their evolutionary significance. *Journal of Human Evolution, 43*(5), 585–603.

Barham, L. S. (2013). *From hand to handle: the first industrial revolution*. Oxford: Oxford University Press.

Barham, L. S., & Mitchell, P. J. (2008). *The first Africans: African archaeology from the earliest tool makers to most recent foragers*. Cambridge: Cambridge University Press.

Barham, L. S., Pinto Llona, A. C., & Stringer, C. (2002). Bone tools from Broken Hill (Kabwe) Cave, Zambia, and their evolutionary significance. *Before Farming* [Online Version] 2002/2: Article 3.

Barkai, R., Rosell, R., Blasco, R., & Gopher, A. (2017). Fire for a reason: barbecue at Middle Pleistocene Qesem Cave, Israel. *Current Anthropology, 58*(Supplement 16), S314–S328.

Barry, D. N., Barnes, G. R., Clark, I. A., & Maguire, E. A. (2019). The neural dynamics of novel scene imagery. *Journal of Neuroscience, 39*(22), 4375–4386.

Bar-Yosef Mayer, D. E., Vandermeersch, B., & Bar-Yosef, O. (2009). Shells and ochre in Middle Paleolithic Qafzeh Cave, Israel: indications for modern behaviour. *Journal of Human Evolution, 56*(3), 307–314.

Beaty, R. E., Kenett, Y. N., Christensen, A. P., Rosenberg, M. D., Benedeke, M., Chen, Q., et al. (2018). Robust prediction of individual creative ability from brain functional connectivity. *Proceedings of the National Academy of Sciences, USA, 115*(5), 1087–1092.

Belfer-Cohen, A., & Hovers, E. (1992). In the eye of the beholder: Mousterian and Natufian burials in the Levant. *Current Anthropology, 33*(4), 463–471.

Belfer-Cohen, A., & Hovers, E., (2020). Prehistoric perspectives on "others" and "strangers" *Frontiers in Psychology*, 10, 3063. https://doi.org/10.3389/fpsyg.2019.03063.

Benoit, R. G., Szpunar, K. K., & Schacter, D. L. (2014). Ventromedial prefrontal cortex supports affective future simulation by integrating distributed knowledge. *Proceedings of the National Academy of Sciences, USA,* 111 (46), 16550–16555.

Berna, F., Goldberg, P., Horwitz, L. K., Brink, J. S., Holt, S., Bamford, M., et al. (2012). Microstratigraphic evidence of in situ fire in the Acheulean strata of Wonderwerk Cave, Northern Cape Province, South Africa. *Proceedings of the National Academy of Sciences, USA, 109*(20), 1215–1220.

Bloch, M. (2013). *In and out of each other's bodies: theory of mind, evolution, truth and the nature of the social*. New York: Paradigm Publishers.

Boëda, E., Connan, J., Dessort, D., Muhesen, S., Mercier, N., Valladas, H., & Tisnérat, N. (1996). Bitumen as a hafting material on Middle Palaeolithic artefacts. *Nature, 380*(6572), 336–338.

Bouzouggar, A., Barton, N., Vanhaeren, M., d'Errico, F., Collcutt, S., Higham, T., et al. (2007). 82,000-year-old shell beads from North Africa and implications for the origins of modern human behavior. *Proceedings of the National Academy of Sciences, USA, 104*(24), 9964–9969.

Bouzouggar, A., Humphrey, L. T., Barton, N., Parfitt, S. A., Balzan, L. C., Schwenninger, J.-L., et al. (2018). 90,000 year-old specialised bone technology in the Aterian Middle Stone Age of North Africa. *PLoS One, 13*(10), e0202021. https://doi.org/10.1371/journal.pone.0202021.

Brain, C. K., & Shipman, P. (1993). The Swartkrans bone tools. In C. K. Brain (Ed.), *Swartkrans: A cave's chronicle of early man* (pp. 195–215). Pretoria: Transvaal Museum.

Bräuer, G. (2001). The KNM-ER 3884 hominid and the emergence of modern anatomy in Africa. In P. V. Tobias, M. A. Raath, J. Moggi-Cecchi, & G. A. Doyle (Eds.), *Humanity from African naissance to coming millennia* (pp. 191–197). Florence: Florence University Press.

Brooks, A. S., Yellen, J. E., Potts, R., Behrensmeyer, A. K., Deino, A. L., & Leslie, D. E. (2018). Long-distance stone transport and pigment use in the earliest Middle Stone Age. *Science, 360*(6384), 90–94.

Brown, K., Marean, C. W., Herries, A. I. R., Jacobs, Z., Tribolo, C., Braun, D., et al. (2009). Fire as an engineering tool of early modern humans. *Science, 325*(5942), 859–862.

Bruner, E. in prep. Evolving human brains: paleoneurology and the fate of Middle Pleistocene. *Journal of Archaeological Method and Theory.*

Cabeza, R., Becker, M., & Davis, S. W. (2020). Are the hippocampus and its network necessary for creativity? *Proceedings of the National Academy of Sciences, USA, 117*(25), 13870–13872.

Cârciumaru, M., Ion, R. M., Niţu, E. C., & Ştefânescu, R. (2012). New evidence of adhesive as hafting material on Middle and Upper Palaeolithic artefacts from Gura Cheii-Râşnov Cave (Romania). *Journal of Archaeological Science, 39*(7), 1942–1950.

Charrié-Duhaut, A., Porraz, G., Cartwright, C. R., Igreja, M., Connan, J., Poggenpoel, C., & Texier, P. J. (2013). First molecular identification of a hafting adhesive in the late Howiesons Poort at Diepkloof Rock Shelter (Western Cape, South Africa). *Journal of Archaeological Science, 40*(9), 3506–3518.

Chermahini, S. A., & Hommel, B. (2010). The (b)link between creativity and dopamine: Spontaneous eye blink rates predict and dissociate divergent and convergent thinking. *Cognition, 115*(3), 458–465.

Clark, J. D., & Brown, K. S. (2001). The Twin Rivers Kopje, Zambia: stratigraphy, fauna, and artefact assemblages from the 1954 and 1956 excavations. *Journal of Archaeological Science, 28*(3), 305–330.

Clarke, R. J. (1985). A new reconstruction of the Florisbad cranium, with notes on the site. In E. Delson (Ed.), *Ancestors: the hard evidence* (pp. 301–305). New York: Alan Liss.

Clarke, R. J. (2012). The history of research in human evolution in Africa and what lessons have been learned. In N. Sanz (Ed.), *Human origin sites and the World Heritage Convention in Africa* (pp. 44–67). Paris: UNESCO.

Cnuts, D., Tomasso, S., & Rots, V. (2017). The role of fire in the life of an adhesive. *Journal of Archaeological Method and Theory*. https://doi.org/10.1007/s10816-017-9361-z.

Colclough, G. L., Smith, S. M., Nichols, T. E., Winkler, A. M., Sotiropoulos, S. N., Glasser, M. F., et al. (2017). The heritability of multi-modal connectivity in human brain activity. *eLife* 2017; 6:e20178. https://doi.org/10.7554/eLife.20178.

Coolidge, F. L. (2019). The enhanced working memory model: its origin and development. In K. A. Overmann & F. L. Coolidge (Eds.), *Squeezing minds from stones: Cognitive archaeology and the evolution of the human mind* (pp. 406–431). Oxford University Press: Oxford.

Coolidge, F. L., Thede, L. L., & Young, S. E. (2000). Heritability and the comorbidity of attention deficit hyperactivity disorder with behavioural disorders and executive function deficits: a preliminary investigation. *Developmental Neuropsychology, 17*(3), 273–287.

Corballis, M. C. (2017). *The truth about language, what it is and where it came from*. Chicago and London: University of Chicago Press.

Cutts, R. B., Hlubik, S., Campbell, R., Muschinski, J., Akuku, P., Braun, D. R., et al. (2019). Thermal curved-fragments: a method for identifying anthropogenic fire in the archaeological record. *Journal of Archaeological Science, 106*, 10–22.

d'Errico, F., & Backwell, L. R. (2016). Earliest evidence of personal ornaments associated with burial: the conus shells from Border Cave. *Journal of Human Evolution, 93*, 91–108.

d'Errico, F., & Henshilwood, C. S. (2007). Additional evidence for bone technology in the southern African Middle Stone Age. *Journal of Human Evolution, 52*, 142–163.

d'Errico, F., & Nowell, A. (2000). Origins of symboling in the Near East: a new look at the Berekhat Ram figurine. *Cambridge Archaeological Journal, 10*(1), 123–167.

d'Errico, F., Vanhaeren, M., & Wadley, L. (2008). Possible shell beads from the Middle Stone Age layers of Sibudu Cave, South Africa. *Journal of Archaeological Science, 35*, 2675–2685.

d'Errico, F., Vanhaeren, M., Barton, N., Bouzouggar, A., Mienis, H., Richter, D., *et al.* (2009). Additional evidence on the use of personal ornaments in the Middle Paleolithic of North Africa. *Proceedings of the National Academy of Sciences, USA*, 106, 16,051–16,056.

d'Errico, F., Salomon, H., Vignaud, C., & Stringer, C. (2010). Pigments from the Middle Palaeolithic levels of Es-Skhul (Mount Carmel, Israel). *Journal of Archaeological Science, 37*, 3099–3110.

d'Errico, F., Backwell, L., & Wadley, L. (2012a). Identifying regional variability in Middle Stone Age bone technology: the case of Sibudu Cave. *Journal of Archaeological Science, 39*, 2479–2495.

d'Errico, F., García Moreno, R., & Rifkin, R. F. (2012b). Technological, elemental and colorimetric analysis of an engraved ochre fragment from the Middle Stone Age levels of Klasies River Cave 1, South Africa. *Journal of Archaeological Science, 39*, 942–952.

Davidson, I., & Noble, W. (1989). The archaeology of perception: traces of depiction and language. *Current Anthropology, 30*(2), 125–155.

Delagnes, A., Schmidt, P., Douze, K., Wurz, S., Bellot-Gurlet, L., Conard, N. J., et al. (2016). Early evidence for the extensive heat treatment of silcrete in the Howiesons Poort at Klipdrift Shelter (Layer PBD, 65 ka), South Africa. *PLoS ONE, 11*(10), e0163874. https://doi.org/10.1371/journal.pone.0163874.

Dirks, P. H. G. M., Berger, L. R., Roberts, E. M., Kramers, J. D., Hawks, J., Randolph-Quinney, P. S., et al. (2015). Geological and taphonomic context for the new hominin species *Homo naledi* from the Dinaledi Chamber, South Africa. *eLife, 4*, e09561.

Dunbar, R., & Shultz, S. (2007). Evolution in the social brain. *Science, 317*, 1344–1347.

Egeland, C. P., Domínguez-Rodrigo, M., Pickering, T. R., Menter, C. G., & Heaton, J. L. (2018). Hominin skeletal part abundances and claims of deliberate disposal of corpses in the Middle Pleistocene. *Proceedings of the National Academy of Sciences, USA, 115*(18), 4601–4606.

Fontana, F., Moncel, M.-H., Nenzioni, G., Onorevoli, G., Peretto, C., & Combier, J. (2013). Widespread diffusion of technical innovations around 300,000 years ago in Europe as a reflection of anthropological and social transformations? New comparative data from the western Mediterranean sites of Orgnac (France) and Cave dall'Olio (Italy). *Journal of Anthropological Archaeology, 32*, 478–498.

Gamble, C., Gowlett, J., & Dunbar, R. (2014). *Thinking big: The evolution of social life and the human mind*. London: Thames and Hudson.

Gibson, N. E., Wadley, L., & Williamson, B. S. (2004). Microscopic residues as evidence of hafting on backed tools from the 60 000 to 68 000 year-old Howiesons Poort layers of Rose Cottage Cave, South Africa. *Southern African Humanities, 16*, 1–11.

Godfrey-Smith, D. I., & Ilani, S. (2004). Past thermal history of goethite and haematite fragments from Qafzeh Cave deduced from thermal activation characteristics of the 1100C TL peak of enclosed quartz grains. *Revue d' Archéométrie, 28*, 185–190.

Green, J., & Spikins, P. (2020). Not just a virtue: the evolution of selfcontrol. *Time and Mind, 13*, 117–139. https://doi.org/10.1080/1751696X.2020.1747246.

Grine, F. E. (2016). The Late Quaternary hominins of Africa: The skeletal evidence from MIS 6–2. In S. Jones & B. A. Stewart (Eds.), *Africa from MIS6–2: Population dynamics and paleoenvironments* (pp. 323–381). Dordrecht: Springer.

Grün, R., Brink, J. S., Spooner, N. A., Taylor, L., Stringer, C. B., Franciscus, R. G., et al. (1996). Direct dating of Florisbad hominid. *Nature, 382*, 500–501.

Haidle, M. N., Garofoli, D., Scheiffele, S., & Stolarczyk, R. E. (in prep.) Fooling around with a piece of scoria – towards a process-oriented perspective in artefact studies. *Journal of Archaeological Method and Theory.*

Henshilwood, C. S., d'Errico, F., Marean, C. W., Milo, R. G., & Yates, R. (2001). An early bone tool industry from the Middle Stone Age at Blombos Cave, South Africa: implications for the origins of modern human behaviour, symbolism and language. *Journal of Human Evolution, 41*, 631–678.

Henshilwood, C. S., d'Errico, F., Yates, R., Jacobs, Z., Tribolo, C., Duller, G. A. T., et al. (2002). The emergence of modern human behaviour: Middle Stone Age engravings from South Africa. *Science, 295*, 1278–1280.

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

Henshilwood, C. S., d'Errico, F., & Watts, I. (2009). Engraved ochres from the Middle Stone Age levels at Blombos Cave, South Africa. *Journal of Human Evolution, 57*, 27–47.

Henshilwood, C. S., d'Errico, F., van Niekerk, K. L., Coquinot, Y., Jacobs, Z., Lauritzen, S.-E., et al. (2011). A 100,000-year-old ochre processing workshop at Blombos Cave, South Africa. *Science, 334*, 219–222.

Henshilwood, C. S., van Niekerk, K. L., Wurz, S., Delagnes, A., Armitage, S. J., Rifkin, R. F., et al. (2014). Klipdrift Shelter, southern Cape, South Africa: preliminary report on the Howiesons Poort layers. *Journal of Archaeological Science, 45*, 284–303.

Hershkovitz, I., Weber, G. W., Quam, R., Duval, M., Grün, R., Kinsley, L., et al. (2018). The earliest modern humans outside Africa. *Science, 359*, 456–459.

Herzlinger, G., Wynn, T., & Goren-Inbar, N. (2017). Expert cognition in the production sequence of Acheulian cleavers at Gesher Benot Ya'aqov, Israel: a lithic and cognitive analysis. *PLoS ONE, 12*(11), e0188337. https://doi.org/10.1371/journal.pone.0188337.

Hill, K. R., Wood, B. M., Baggio, J., Hurtado, A. M., & Boyd, R. T. (2014). Hunter-gatherer inter-band interaction rates: Implications for cumulative culture. *PLoS One, 9*(7), e102806. https://doi.org/10.1371/journal.pone.0102806.

Hodgskiss, T. (2013). Ochre use in the Middle Stone Age at Sibudu, South Africa: grinding, rubbing, scoring and engraving. *Journal of African Archaeology, 11*, 75–95.

Hovers, E., Ilani, S., Bar-Yosef, O., & Vandermeersch, B. (2003). An early case of color symbolism: ochre use by modern humans in Qafzeh Cave. *Current Anthropology, 44*, 491–522.

Hublin, J.-J., Ben-Ncer, A., Bailey, S. E., Freidline, S. E., Neubauer, S., Skinner, M. M., et al. (2017). New fossils from Jebel Irhoud, Morocco and the pan-African origin of *Homo sapiens*. *Nature, 546*, 289–292.

Hutchins, E. (2010). Enaction, imagination, and insight. In J. Stewart, O. Capenne, & E. A. di Paolo (Eds.), *Enaction: Towards a new paradigm for cognitive science* (pp. 425–450). Cambridge Massachusetts: MIT Press.

Irish, J. D., Bailey, S. E., Guatelli-Steinberg, D., Delezene, L. K., & Berger, L. R. (2018). Ancient teeth, phenetic affinities, and African hominins: another look at where *Homo naledi* fits in. *Journal of Human Evolution, 122*, 108–123.

Jacobs, J., Roberts, R. G., & Nespoulet, R. (2012). Single-grain OSL chronologies for Middle Palaeolithic deposits at El Mnasra and El Harhoura 2, Morocco: implications for Late Pleistocene human environment interactions along the Atlantic coast of northwest Africa. *Journal of Human Evolution, 62*, 377–394.

Kaminski, J. A., Schlagenhauf, F., Rapp, M., Awasthi, S., Rugger, B., Deserno, L., et al. (2018). Epigenetic variance in dopamine D2 receptor: a marker of IQ malleability? *Translational Psychiatry, 8169*. https://doi.org/10.1038/s41398-018-0222-7.

Kanwisher, N., & Yovel, G. (2006). The fusiform face area: a cortical region specialized for the perception of faces. *Philosophical Transactions of the Royal Society of London, B Biological Science, 361*(1476), 2109–2128.

Lombard, M. (2006). Direct evidence for the use of ochre in the hafting technology of Middle Stone Age tools from Sibudu Cave, KwaZulu-Natal. *Southern African Humanities, 18*(1), 57–67.

Lombard, M. (2007). The gripping nature of ochre: the association of ochre with Howiesons Poort adhesives and Later Stone Age mastics from South Africa. *Journal of Human Evolution, 53*, 406–419.

Lombard, M., & Haidle, M. N. (2012). Thinking a bow-and-arrow set: cognitive implications of Middle Stone Age bow and stone-tipped arrow technology. *Cambridge Archaeological Journal, 22*(2), 237–264.

Mackay, A., & Welz, A. (2008). Engraved ochre from a Middle Stone Age context at Klein Kliphuis in the Western Cape of South Africa. *Journal of Archaeological Science, 35*, 1521–1532.

Mackay, A., Stewart, B. A., & Chase, B. M. (2014). Coalescence and fragmentation in the late Pleistocene archaeology of southernmost Africa. *Journal of Human Evolution, 72*, 26–51.

Malafouris, L. (2008). Beads for a plastic mind: the "blind man's stick" (BMS) hypothesis and the active nature of material culture. *Cambridge Archaeological Journal, 18*(3), 401–414.

Malafouris, L. (2013). *How things shape the mind: a theory of material engagement*. Cambridge, Massachusetts, London: MIT Press.

Malafouris, L. (in prep.) How do humans become? Marks as creative gestures in human evolution. *Journal of Archaeological Method and Theory.*

Marean, C. W., Bar-Matthews, M., Bernatchez, J., Fisher, E., Goldberg, P., Herries, A. I. R., et al. (2007). Early human use of marine resources and pigment in South Africa during the Middle Pleistocene. *Nature, 449*, 905–908.

McBrearty, S. (2001). The Middle Pleistocene of East Africa. In L. H. Barham & K. Robson-Brown (Eds.), *Human roots: Africa and Asia in the Middle Pleistocene* (pp. 81–97). Bristol: Western Academic and Specialist Press.

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

McBrearty, S., & Tryon, C. (2006). From Acheulean to Middle Stone Age in the Kapthurin Formation, Kenya. In E. Hovers & S. L. Kuhn (Eds.), *Transitions before the transition: Evolution and stability in the Middle Palaeolithic and Middle Stone Age* (pp. 257–277). New York: Springer.

Mehlman, M. J. (1987). Provenience, age and association of archaic *Homo sapiens* crania from Lake Eyasi, Tanzania. *Journal of Archaeological Science, 14*, 133–162.

Migliano, A. B., Battiston, F., Viguier, S., Page, A. E., Dyble, M., Schlaepfer, R., et al. (2020). Hunter-gatherer multilevel sociality accelerates cumulative cultural evolution. *Science Advances, 6: eaax5913*, (28 February 2020).

Miller, J. M., & Willoughby, P. R. (2014). Radiometrically dated ostrich eggshell beads from the Middle and Later Stone Age of Magubike Rockshelter, southern Tanzania. *Journal of Human Evolution, 74*, 118–122.

Mithen, S. (1996). *The prehistory of the mind*. London: Thames & Hudson.

Morley, M. W., Goldberg, P., Uliyanov, V. A., Kozlikin, M. B., Shunkov, M. V., Derevianko, A. P., *et al.* (2019). Hominin and animal activities in the microstratigraphic record from Denisova Cave (Altai Mountains, Russia). *Scientific Reports* 9, 13,785| https://doi.org/10.1038/s41598-019-49930-3.

Mourre, V., Villa, P., & Henshilwood, C. S. (2010). Early use of pressure flaking on lithic artifacts at Blombos Cave, South Africa. *Science, 330*, 659–662.

Mullally, S. L., & Maguire, E. A. (2014). Memory, imagination, and predicting the future: a common brain mechanism? *Neuroscientist, 20*(3), 220–234.

Parkington, J., Poggenpoel, C., Rigaud, J.-P., & Texier, P.-J. (2005). From tool to symbol: the behavioural context of intentionally marked ostrich eggshell from Diepkloof, Western Cape. In F. d'Errico & L. Backwell (Eds.), *From tools to symbols: from early hominids to modern humans* (pp. 475–492). Johannesburg: Witwatersrand University Press.

Posth, C., Wißing, C., Kitagawa, K., Pagani, L., van Holstein, L., Racimo, F., et al. (2017). Deeply divergent archaic mitochondrial genome provides lower time boundary for African gene flow into Neanderthals. *Nature Communications, 8*, 16,046 (2017).

Powell, A., Shennan, S., & Thomas, M. G. (2009). Late Pleistocene demography and the appearance of modern human behavior. *Science, 324*, 1298–1301.

Roberts, P. (2016). We have never been 'behaviourally modern': the implications of Material Engagement Theory and Metaplasticity for understanding the Late Pleistocene record of human behaviour. *Quaternary International, 405*, 8–20.

Roebroeks, W., & Villa, P. (2011). On the earliest evidence for habitual use of fire in Europe. *Proceedings of the National Academy of Sciences, USA, 108*(13), 5209–5214.

Roebroeks, W., Sier, M. J., Nielsen, T. K., De Loecker, D., Parés, J. M., Arps, C. E. S., et al. (2012). Use of red ochre by early Neandertals. *Proceedings of the National Academy of Science, USA, 109*, 1889–1894.

Rosell, J., Blasco, R., Campeny, G., Díez, J. C., Alonso Alcalde, R., Menéndez, L., et al. (2011). Bone as a technological raw material at the Gran Dolina site (Sierra de Atapuerca, Burgos, Spain). *Journal of Human Evolution, 61*, 125–131.

Rots, V., & van Peer, P. (2006). Early evidence of complexity in lithic economy: core-axe production, hafting and use at Late Middle Pleistocene site 8-B-11, Sai Island (Sudan). *Journal of Archaeological Science, 33*, 360–371.

Rots, V., van Peer, P., & Vermeersch, P. M. (2011). Aspects of tool production, use, and hafting in Palaeolithic assemblages from Northeast Africa. *Journal of Human Evolution, 60*, 637–664.

Sahle, Y., Hutchings, W. K., Braun, D. R., Sealy, J. C., Morgan, L. E., Negash, A., et al. (2013). Earliest stone-tipped projectiles from the Ethiopian rift date to >279,000 years ago. *PloS One, 8*(11), e78092.

Sandgathe, D. M. (2017). Identifying and describing pattern and process in the evolution of hominin use of fire. *Current Anthropology, 58*(Supplement 16), S360–S370.

Scerri, E. M. L., Lounès Chikhi, L., & Thomas, M. G. (2019). Beyond multiregional and simple out-of-Africa models of human evolution *Nature Ecology and Evolution,* www.nature.com/natecolevol

Schlebusch, C. M., & Jakobsson, M. (2018). Tales of human migration, admixture, and selection in Africa. *Annual Review of Genomics and Human Genetics,* ***19***, 10.1–10.24.

Schmidt, P., Porraz, G., Bellot-Gurlet, L., February, E., Ligouis, B., Paris, C., et al. (2015). A previously undescribed organic residue sheds light on heat treatment in the Middle Stone Age. *Journal of Human Evolution, 85*, 22–34.

Schwertmann, U., & Cornell, R. M. (1991). *Iron oxides in the laboratory: preparation and characterization*. Cambridge: VCH.

Seitz, J. A. (2000). The bodily basis of thought. *New Ideas in Psychology, 18*, 23–40.

Singer, R., & Wymer, J. (1982). *The Middle Stone Age at Klasies River Mouth in South Africa*. Chicago: Chicago University Press.

Sorensen, A., Roebroeks, W., & van Gijn, A. (2014). Fire production in the deep past? The expedient strike-a-light model. *Journal of Archaeological Science, 42*, 476–486.

Stade, C., & Gamble, C. (2019). In three minds: extending cognitive archaeology with the social brain. In K. A. Overmann & F. L. Coolidge (Eds.), *Squeezing minds from stones: Cognitive archaeology and the evolution of the human mind* (pp. 319–331). Oxford: Oxford University Press.

Stiner, M. C., Gopher, A., & Barkai, R. (2011). Hearth-side socioeconomics, hunting and paleoecology during the late Lower Paleolithic at Qesem Cave, Israel. *Journal of Human Evolution, 60*, 213–233.

Stout, D. (2019). *Homo artifex*: an extended evolutionary perspective on the origins of the human mind, brain, and culture. In K. A. Overmann & F. L. Coolidge (Eds.), *Squeezing minds from stones: Cognitive archaeology and the evolution of the human mind* (pp. 42–58). Oxford: Oxford University Press.

Stout, D., & Hecht, E. E. (2017). Evolutionary neuroscience of cumulative culture. *Proceedings of the National Academy of Science, USA, 114*(30), 7861–7786.

Stout, D., Passingham, R., Frith, C., Apel, J., & Chaminade, T. (2011). Technology, expertise and social cognition in human evolution. *European Journal of Neuroscience, 33*, 1328–1338.

Sun, Q., Li, X., Li, A., Zhang, J., Ding, Z., Gong, H., & Luo, Q. (2020). Ventral hippocampal-prefrontal interaction affects social behavior *via* parvalbumin positive neurons in the medial prefrontal cortex. *iScience, 23*, 100,894. https://doi.org/10.1016/j.isci.2020.100894.

Texier P.-J., Porraz, G., Parkington, J. E., Rigaud, J.-P., Poggenpoel, C., Miller, C. E., *et al.* (2010). Howiesons Poort tradition of engraving ostrich eggshell containers dated to 60,000 years ago at Diepkloof Rock Shelter, South Africa. *Proceedings of the National Academy of Science*, *USA*, 107, 6180–6185.

Texier, P.-J., Porraz, G., Parkington, J. E., Rigaud, J.-P., Poggenpoel, C., Miller, C. E., et al. (2013). The context, form and significance of the MSA engraved ostrich eggshell collection from Diepkloof Rock Shelter, Western Cape, South Africa. *Journal of Archaeological Science, 40*, 3412–3431.

Tryon, C. A., Lewis, J. E., Ranhorn, K. L., Kwekason, A., Alex, B., Laird, M. F., et al. (2018). Middle and Later Stone Age chronology of Kisese II rockshelter (UNESCO World Heritage Kondoa Rock-Art Sites), Tanzania. *PLoS ONE, 13*(2), e0192029. https://doi.org/10.1371/journal.pone.0192029.

Van Peer, P., Fullagar, R., Stokes, S., Bailey, R. M., Moeyersons, J., Steenhoudt, F., et al. (2003). The Early to Middle Stone Age transition and the emergence of modern human behaviour at site 8-B-11, Sai Island, Sudan. *Journal of Human Evolution, 45*, 187–193.

Van Peer, P., Rots, V., & Vroomans, J. M. (2004). A story of colourful diggers and grinders: the Sangoan and Lupemban at site 8-B-11, Sai island, northern Sudan. *Before Farming* [Online Version], 2004/3: Article 1.

Vanhaeren, M., d'Errico, F., Stringer, C., James, S. L., Todd, J. A., & Mienis, H. K. (2006). Middle Paleolithic shell beads in Israel and Algeria. *Science, 312*, 1785–1788.

Vanhaeren, M., d'Errico, F., van Niekerk, K. L., Henshilwood, C. S., & Erasmus, R. M. (2013). Thinking strings: additional evidence for personal ornament use in the Middle Stone Age at Blombos Cave, South Africa. *Journal of Human Evolution, 64*, 500–517.

Vanhaeren, M., Wadley, L., & d'Errico, F. (2019). Variability in Middle Stone Age symbolic traditions: the marine shell beads from Sibudu Cave, South Africa. *Journal of Archaeological Science, Reports, 27*, 101, 893.

Villa, P., Pollarolo, L., Degano, I., Birolo, L., Pasero, M., Biagioni, C., et al. (2015). A milk and ochre paint mixture used 49,000 years ago at Sibudu, South Africa. *PLoS ONE, 10*(6), e0131273. https://doi.org/10.1371/journal.pone.0131273.

Vogelsang, R. (1998). *Middle Stone Age fundstellen in Südwest-Namibia*. Köln: Heinrich Barth Institut.

Wadley, L. (2010). Compound-adhesive manufacture as a behavioral proxy for complex cognition in the Middle Stone Age. *Current Anthropology*, 51 (Supplement 1), S111–S119.

Wadley, L. (2015). Those marvellous millennia: the Middle Stone Age of Southern Africa. *Azania: Archaeological Research in Africa, 50*(2), 155–226.

Wadley, L., Hodgskiss, T., & Grant, M. (2009). Implications for complex cognition from the hafting of tools with compound adhesives in the Middle Stone Age, South Africa. *Proceedings of the National Academy of Sciences, USA*, 106, 9590–9594.

Walker, M. J., Anesin, D., Angelucci, D. E., & Avilés-Fernández, A. (2016). Combustion at the late Early Pleistocene site of Cueva Negra del Estrecho del Río Quípar (Murcia, Spain). *Antiquity, 90*(351), 571–589.

Watts, I. (2010). The pigments from Pinnacle Point Cave 13B, Western Cape, South Africa. *Journal of Human Evolution, 59*, 392–411.

Watts, I., Chazan, M., & Wilkins, J. (2016). Early evidence for brilliant ritualized display: Specularite use in the Northern Cape (South Africa) between ~500 and ~300 ka. *Current Anthropology, 57*(3), 287–310.

Welshon, R. (2019). Looking at rocks together: tool production, joint attention, and offline cognition. In K. A. Overmann & F. L. Coolidge (Eds.), *Squeezing minds from stones: Cognitive archaeology and the evolution of the human mind* (pp. 59–78). Oxford: Oxford University Press.

Wendt, W. E. (1972). Preliminary report on an archaeological research programme in South West Africa. *Cimbebasia, Series B, 2*, 1–61.

Wilkins, J., & Chazan, M. (2012). Blade production ~500 thousand years ago at Kathu Pan 1, South Africa: support for a multiple origins hypothesis for early Middle Pleistocene blade technologies. *Journal of Archaeological Science, 37*, 269–283.

Wilkins, J., Schoville, B. J., Brown, K. S., & Chazan, M. (2012). Evidence for early hafted hunting technology. *Science, 338*, 942–946.

Will, M., Kandel, A. W., & Conard, N. J. (2019). Midden or molehill: the role of coastal adaptations in human evolution and dispersal. *Journal of World Prehistory*. https://doi.org/10.1007/s10963-018-09127-4.

Wojcieszak, M., & Wadley, L. (2018). Raman spectroscopy and scanning electronic microscopy confirm ochre residues on 71,000 year old bifacial tools from Sibudu, South Africa. *Archaeometry, 60*(5), 1062–1076.

Wynn, T., & Berlant, T. (2019). The handaxe aesthetic. In K. A. Overmann & F. L. Coolidge (Eds.), *Squeezing minds from stones: cognitive archaeology and the evolution of the human mind* (pp. 278–303). Oxford: Oxford University Press.

Wynn, T., Haidle, M., Lombard, M., & Coolidge, F. L. (2017). The expert cognition model in human evolutionary studies. In T. Wynn & F. L. Coolidge (Eds.), *Cognitive models in Palaeolithic archaeology* (pp. 21–43). Oxford: Oxford University Press.

Yellen, J. E., Brooks, A. S., Cornelissen, E., Mehlman, M. J., & Stewart, K. (1995). A Middle Stone Age worked bone industry from Katanda, Upper Semliki Valley, Zaire. *Science, 268*, 553–556.
Zipkin, A. M., Wagner, M., McGrath, K., Brooks, A. S., & Lucas, P. W. (2014). An experimental study of hafting adhesives and the implications for compound tool technology. *PLoS One, 9*(11), e112560.