The evolution of early symbolic behavior in *Homo sapiens*

Kristian Tylén[a,b,1], Riccardo Fusaroli[a,b], Sergio Rojo[a,2], Katrin Heimann[b], Nicolas Fay[c], Niels N. Johannsen[b,d], Felix Riede[b,d], and Marlize Lombard[e]

[a]Department of Linguistics, Cognitive Science and Semiotics, Aarhus University, 8000 Aarhus C, Denmark; [b]Interacting Minds Centre, Aarhus University, 8000 Aarhus C, Denmark; [c]School of Psychological Science, University of Western Australia, Perth, WA 6009, Australia; [d]Department of Archaeology and Heritage Studies, Aarhus University, 8270 Højbjerg, Denmark; and [e]Palaeo-Research Institute, University of Johannesburg, Auckland Park, 2006 Johannesburg, South Africa

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How did human symbolic behavior evolve? Dating up to about 100,000 y ago, the engraved ochre and ostrich eggshell fragments from the South African Blombos Cave and Diepkloof Rock Shelter provide a unique window into presumed early symbolic traditions of *Homo sapiens* and how they evolved over a period of more than 30,000 y. Using the engravings as stimuli, we report five experiments which suggest that the engravings evolved adaptively, becoming better-suited for human perception and cognition. More specifically, they became more salient, memorable, reproducible, and expressive of style and human intent. However, they did not become more discriminable over time between or within the two archeological sites. Our observations provide support for an account of the Blombos and Diepkloof engravings as decorations and as socially transmitted cultural traditions. By contrast, there was no clear indication that they served as denotational symbolic signs. Our findings have broad implications for our understanding of early symbolic communication and cognition in *H. sapiens*.

symbolic behavior | human cognition | evolution | archeology

A central hallmark in the evolution and success of *Homo sapiens* as a species is the appearance of so-called modern human behavior comprising sophisticated cognitive and instrumental skill, social organization, and fully developed symbol use (1, 2). Recent findings in the sub-Saharan Africa have established what appears to be advanced cognitive and symbolic behavior in the Middle Stone Age dating back more than 100,000 y (2, 3). Central among these are patterns engraved in ochre pieces from Blombos (4) and ostrich eggshell fragments from Diepkloof (5) (Fig. 1). Whereas there is broad consensus that these patterns are ancient expressions of symbolic behavior, their origin and function have been the subject of extensive discussion and speculation (4–11). However, the compositional development of the engraved patterns over time might contain clues to their function.

The engraved ochres from the Blombos Cave are associated with the Still Bay technocomplex (12). They were found throughout a series of stratigraphic layers dated to phases of the African Middle Stone Age, indicating a tradition of engraving at the site spanning more than 30,000 y, with early patterns dating back *ca*. 100,000 y and the later ones >70,000 y (4). The egg shell engravings from the Diepkloof Rock Shelter are associated with the Howiesons Poort technocomplex (12) and are thought to span the period from *ca*. 109,000 to *ca*. 52,000 y ago (10, 13, 14), yet controversy exists over the precise dating of the Diepkloof sequence (15, 16). Although the materials are different (ochre and ostrich egg shell) and their chronologies might not coincide, and there is no direct evidence of contact between the groups inhabiting the two sites (separated by approximately 400 km; Fig. 1), there are striking similarities in the compositions of engraved patterns and how they evolved over time (ref. 11 and see also *SI Appendix*, Fig. S1). This compositional development—from simple configurations of parallel lines to complex cross-hatchings, characterized by greater symmetry and cardinal and diagonal lines—may reflect a cumulative cultural process during which the engravings evolved adaptively to more efficiently serve their cognitive functions as symbols (2, 7, 10, 11).

Symbolic artifacts are tools of the mind. While instrumental tools (e.g., stone axes) are employed to make changes to the physical environment, symbolic artifacts are employed to facilitate cognitive practices of reasoning, communication, and aesthetics (17–19). In order to do so, symbols need to resonate with the cognitive system of the user, implying that they are designed and refined over time to fit human cognitive systems of perception, memory, attention, and reasoning (20–23). However, the term "symbolic" is often underspecified and used to refer to a wide range of human expressive behaviors, including aesthetic practices of decoration and ornamentation, rituals and music, time and account keeping, and language and narrative. In discussions of the symbolic nature of the Blombos and Diepkloof engravings they have been portrayed as 1) aesthetic decorations (11, 24), 2) markers of sociocultural identity (10), or 3) fully developed denotational symbols (7). All three suggestions are symbolic in the sense that the engravings are intended to induce cognitive effects, yet they differ with respect to the particular

Significance

Early symbolic behavior of *Homo sapiens* is challenging to address yet arguably fundamental to the success of our species. We used ancient engravings from the South African Blombos Cave and Diepkloof Rock Shelter in a number of controlled cognitive experiments to qualify discussions about the evolution of early symbolic traditions. We found that the engravings evolved over a period of 30,000 y to become more effective "tools for the mind," that is, more salient to the human eye, increasingly expressive of human intent and identity, and easier to reproduce from memory. Our experiments suggest that the engravings served as decorations and expressions of socially transmitted cultural traditions, while we found no clear evidence that they served as denotational symbolic signs.

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[1]To whom correspondence may be addressed. Email: kristian@cc.au.dk.

[2]Present address: Centre for Languages and Literature, Lund University, 22100 Lund, Sweden.

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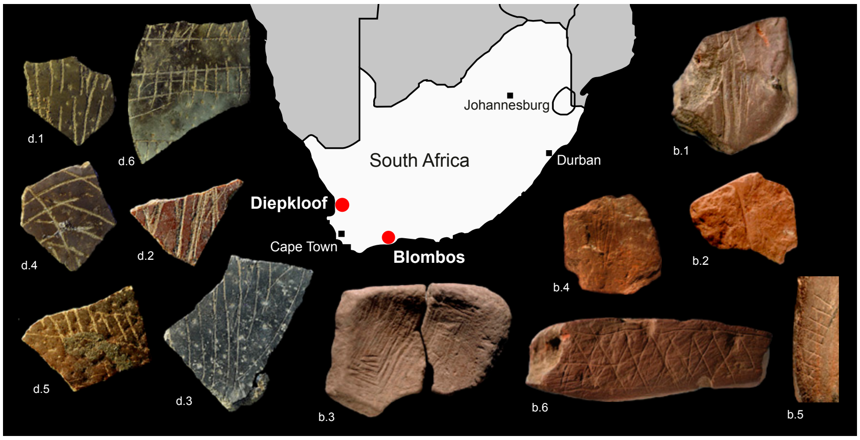

Fig. 1. Map showing the location of the Blombos Cave and the Diepkloof Rock Shelter. Artifacts d.1 through d.6 are engraved ostrich eggshell fragments from Diepkloof. Objects b.1 through b.6 are engraved ochre nodules from Blombos. In both cases, the numbering reflects the relative, within-site dating of items, with d.1, d.2, b.1 and b.2 being from the early part of the period; d.3, d.4, b.3, and b.4 from the intermediate period; and d.5, d.6, b.5, and b.6 from the late period. Photographic materials adapted from ref. 7 and ref. 10, with permission from Elsevier.

symbolic function, that is, the kind of meaning they signify, and, critically, therefore also to the underlying cognitive processes involved (25–27).

The aesthetic resonance hypothesis (H1) holds that the Blombos and Diepkloof engravings were produced for aesthetic appreciation (11, 28). The patterns were composed to stimulate the human visual system and evolved to effectively induce such pleasurable aesthetic effects. On this account, the patterns served as nonreferential, self-sufficient marks driven by visual saliency and catering to "private" aesthetic pleasure (11). Following H1, we predict that as humans became more skillful in producing patterns for the purpose of aesthetic pleasure they evolved to become more salient to the human eye ($H1_{p1}$) (11, 24) and increasingly recognizable as purposefully produced by humans ($H1_{p2}$).

Another suggestion, henceforth called the cultural connotation hypothesis (H2), holds that the Blombos and Diepkloof engravings served a social function, as markers of group identity (10). Along with practices of artifact production and decoration, systematic stylistic variations may evolve to become signifiers of socially transmitted group identity (29, 30). Style has often been assumed to be indicative of capacities for symbolic cognition (9, 31, 32), yet stylistic elements are also observed to be habitually reproduced as part of cultural traditions not necessarily implying overt intentions on behalf of the producer. This suggests that the social meaning of style can be an associative "symptom" of its producer (26), quite different from the way words relate to their meanings through intentional, conventional reference (cf. the distinction between active and passive style, ref. 33). If the Blombos and Diepkloof patterns formed part of a practice of signifying group affiliation, it follows that they should have evolved over time to become 1) easier to remember and reproduce ($H2_{p1}$), 2) easier to recognize as belonging to one of the two sites ($H2_{p2}$), and 3) faster to discriminate if belonging to different sites than if they belonged to the same site ($H2_{p3}$).

A third approach articulated in the literature, the symbolic denotation hypothesis (H3), takes interpretations of the Blombos and Diepkloof engravings a step further, suggesting that they served as fully developed referential, denotational symbols (7). This perspective assumes that the patterns were intentionally produced for a representational purpose with patterns pointing arbitrarily to their individual referential meaning by convention (6, 26, 34), similar to orthographic glyphs or words (4). For a denotational symbol system to be effective, the individual symbolic forms should be easy to discriminate in order not to confuse forms pointing to different meanings. On this account, the patterns evolved to optimize discriminability between signs within each of the archeological sites ($H3_{p1}$) (35–37).

Importantly, the three symbolic functions hypothesized above are not necessarily mutually exclusive. In fact, practices of symbolic denotation may have evolved from simpler expressive practices (iconic and indexical signs, ref. 27), and artifacts originally intended for one function have been observed to be adopted for other functions (38, 39). Both aesthetic and denotational artifacts can display elements of style (40).

Human thoughts and intentions do not fossilize, and it is thus a major challenge to discern if the Blombos and Diepkloof engravings were made for aesthetic appreciation or served as markers of group identity or for symbolic communication. So far, theories remain speculative and rely exclusively on inferences drawn from analyses of the material artifacts alone.

Experimental investigations with contemporary humans have previously proven informative about the cognitive and behavioral processes possibly underlying ancient lithic tool production (41–44). However, no such investigations have addressed symbolic behavior. To advance our understanding of the cognitive nature and evolution of early symbolic behavior in *H. sapiens*, we experimentally test a number of concrete predictions derived from the literature. While the human cognitive system has undoubtedly been subject to some genetic change since the Middle Stone Age, researchers across disciplines are increasingly endorsing models of gene–culture coevolution, emphasizing the impact of cultural processes on human evolution (23, 45–47). The experimental approach taken here relies on the assumption that despite genetic and cross-cultural variation, the commonalities (e.g., of low-level visual processes, many of which are also shared across primates, refs. 48–50) between late Middle Stone Age and contemporary humans are sufficient to render comparisons meaningful and informative (see also refs. 2, 28, and 51–53).

Using five experimental investigations, we compare the cognitive properties of engravings belonging to different stages of the evolutionary trajectory to inform cumulative inferences about their adaptive development for particular symbolic functions. All of the experiments use the engraved patterns as stimuli: From the published pattern outlines we derived a corpus of controlled stimuli, conserving pattern compositions while keeping other parameters constant, such as the number and length of individual lines (Fig. 2 and see also *SI Appendix*).

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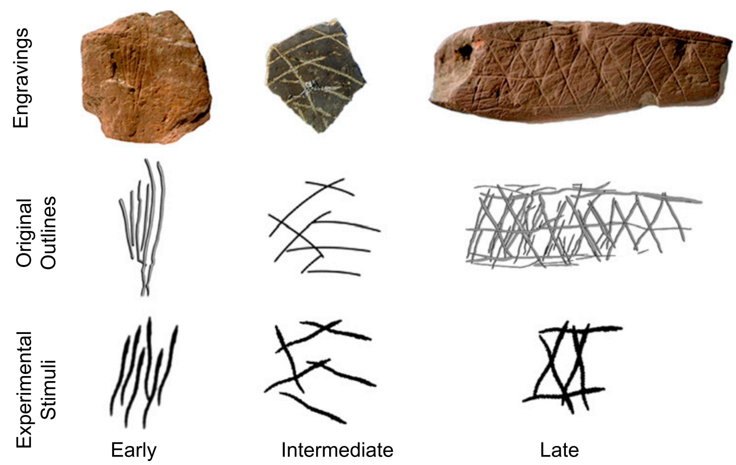

Fig. 2. Examples illustrating the steps involved in generation of experimental stimuli. In order to isolate compositional elements of the patterns while controlling for number and length of lines, stimulus patterns were created from the published outlines consisting of six lines of equal length. (*Top*) The original engraved artifacts. (*Middle*) The published outlines. (*Bottom*) The derived experimental stimuli. The columns represent pattern from three different stages of the evolutionary trajectory. Photographic materials adapted from ref. 7 and ref. 10, with permission from Elsevier.

Results

To test if the engraved patterns evolved to become more salient to the human eye as predicted by the $H1_{p1}$, Experiment 1 used continuous flash suppression, a psychophysical technique utilizing the phenomenon of binocular rivalry to derive a measure of low-level visual salience (54, 55). Using a mirror stereoscope, we projected patches of vivid flickering colors to the dominant eye of participants while presenting outlines of the engraved patterns to the nondominant eye (*SI Appendix*, Fig. S4). While the experimental stimuli are initially suppressed by the flickering colors, after a variable delay they gain perceptual dominance and enter conscious perception. This variable time to emerge has been shown to be indicative of the low-level visual salience of the stimuli, with more-salient stimuli gaining perceptual dominance faster than nonsalient stimuli (55).

The time it took for a stimulus pattern to enter conscious perception got shorter as a function of period with faster reaction times for the later (younger) patterns compared to the earlier (older) ones. On average, earlier stimulus engravings were identified in 2.27 s, intermediate stimuli in 2.03 s, and late ones in 1.82 s (evidence ratio, ER, for a negative slope against all alternatives > 1,000; Fig. 3*A* and *SI Appendix*, Table S2). Control tests suggest a similar development over time for the two archeological sites (no credible interaction between site and period; *SI Appendix*). In summary, the engraved patterns from the Blombos and Diepkloof sites evolved to become increasingly salient to the visual system, supporting the aesthetic resonance theory.

To test if the patterns evolved to be recognized as more intentional over time ($H1_{p2}$), Experiment 2 presented participants with a two-item forced-choice paradigm. At each trial, participants were presented with a pair of stimuli patterns and asked to indicate which of the two they thought was more likely to have been purposefully made by a human. After presenting all possible pairs of stimuli, we ranked items relative to each other as being perceived as more or less intentionally produced. As predicted by the H1, participants recognized the later patterns as intentionally produced more often than the earlier patterns (ER for a positive effect against all alternatives = 587; Fig. 3*B* and *SI Appendix*, Table S3). Again, the effects were similar across the two sites (no interactions between period and site; *SI Appendix*).

To test if the Blombos and Diepkloof engravings evolved to become easier to remember and reproduce, as predicted by the $H2_{p1}$, Experiment 3 presented participants with a delayed reproduction task. In each trial, participants were shown a pattern for 3 s, which then disappeared. After a delay of 2 s, participants were instructed to reproduce the pattern as accurately as possible. Participants' ability to remember and reproduce the engraved patterns varied as a function of period, with later patterns being reproduced with higher fidelity (less error), than earlier patterns (ER for a negative effect against all alternatives = 888; Fig. 3*C* and *SI Appendix*, Table S4). Again, these effects were similar across the two archeological sites. Consistent with the H2, the engravings evolved to become easier to sustain and reproduce from memory.

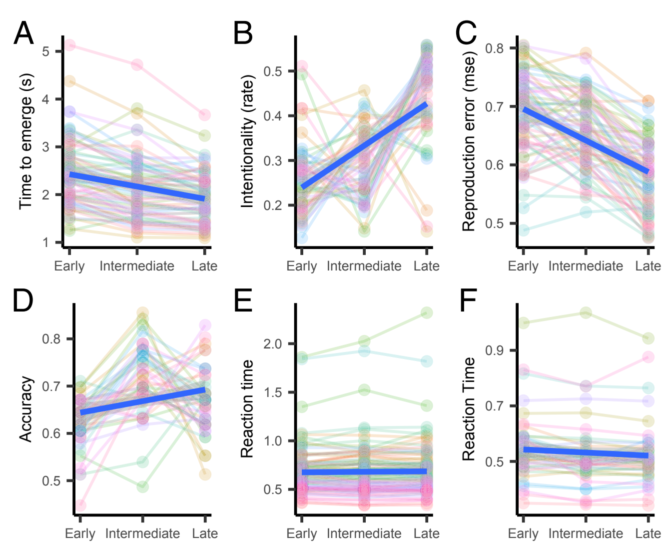

Fig. 3. Results of Experiments 1 through 5. The blue regression lines represent the general linear effect of period and colored lines represent individual means for each participant, for each of the three periods. (*A*) Experiment 1: time to emerge as a function of period. (*B*) Experiment 2: propensity to recognize a pattern as intentionally produced as a function of period. (*C*) Experiment 3: reproduction fidelity (error) as a function of period. (*D*) Experiment 4: accuracy in matching a pattern with another one from the same site as a function of period. (*E*) Experiment 5a: reaction time in between-site discrimination of patterns as a function of period. (*F*) Experiment 5b: reaction time in within-site discrimination of patterns as a function of period.

To test the second prediction ($H2_{p2}$) that, due to the emergence of style, it became increasingly easier to recognize patterns as belonging to the same or different sites, Experiment 4 presented participants with a pair of competitor stimulus patterns (one from Blombos and one from Diepkloof) and a target (from Blombos or Diepkloof) in a two-item forced-choice reaction-time paradigm. Participants were instructed to indicate which of the two competitor patterns they thought belonged together with the target pattern. Response accuracy increased as a function of period (ER for a positive effect against all alternatives = 101.56; Fig. 3*D* and *SI Appendix*, Table S5), and speed of accurate response got faster (ER for a negative effect against all alternatives = 48.69; *SI Appendix*, Table S6). These findings suggest the patterns evolved site-specific styles over time, making it easier to recognize patterns as belonging to a specific site.

To test the third prediction ($H2_{p3}$) that over time it became easier (faster) to discriminate between patterns originating from different sites, Experiment 5 used a discrimination task. Participants were presented with a pair of competitor stimulus patterns and a target in a two-item forced-choice reaction-time paradigm. They were instructed to indicate as fast as possible which of the two competitors was identical to the target (presented in different orientations). Discriminability between patterns from the two sites did not increase as a function of chronological period (ER for a negative effect against all alternatives = 0.18, Bayes factor of the null against the alternative hypothesis, BF01, = 9.42; Fig. 3*E* and *SI Appendix*, Table S9). This suggests that the engraved patterns did not evolve to become more discriminable between sites, as would be predicted if they served as explicit markers of group identity.

In summary, whereas we observe the patterns to become easier to learn, reproduce, and associate with other patterns from the same site, they did not become more discriminable between the two sites, which was also predicted by the H2.

To test if the engravings evolved to optimize discriminability between patterns within each of the archeological sites as predicted by the $H3_{p1}$, we again relied on data from Experiment 5. An increase in discriminability within the two sites could imply that the patterns were under adaptive pressure to become more distinguishable, pointing to their potential involvement in a system of denotational symbols. However, discriminability between patterns from within the same site did not increase as a function of chronological period (ER for a negative effect against all alternatives = 0.18, BF01 = 9.42; Fig. 3*F* and *SI Appendix*, Table S9). In other words, the experimental data do not support the H3.

Discussion

Investigating the early evolution of human symbolic behavior entails making inferences about the cognitive processes and social practices of people living in southern Africa many millennia ago. Cognitive processes do not fossilize and we are left only with the sparse material remains of such processes, which are often ambiguous with respect to their original intention and function. The Blombos and Diepkloof engravings are special compared to other findings of early communicative and symbolic behaviors: Within the constrained locations of the Blombos Cave and Diepkloof Rock Shelter, we have the material remains of deliberate engraving practices spanning more than 30,000 y. This makes it possible to study how these practices changed over time and from these changes to generate inferences about their cognitive function.

We have taken an experimental approach that makes direct use of the archaeological evidence to provide a number of online cognitive measures to quantitatively inform discussions about the possible cognitive functions of the Blombos and Diepkloof engravings. Our findings support a view of the engravings as products of a cumulative cultural development toward more complex patterns with increasingly structured and symmetric line crossings (11, 24, 28), which make them more salient to the human eye, more recognizable as intentionally made, easier to reproduce from memory, and easier to recognize as belonging to a specific group. These properties have been shown to make symbolic forms easier for the visual system to process (56) and are found to be associated with human aesthetic preferences (28, 57, 58) and modern orthographic systems (59). In other words, they track Middle Stone Age *H. sapiens* becoming increasingly skilled in producing engravings that resonate with the human cognitive system in effective ways.

Our findings provide strong support for the H1, which predicts that the Blombos and Diepkloof engravings were produced with aesthetic intentions and served as decorations (11, 24, 28). However, there was also evidence that they evolved to become easier to remember and reproduce (Experiment 3), suggesting they have been subject to adaptive pressures for learnability. Similarly, the later patterns were easier to recognize as belonging to the same archeological site compared to the earlier patterns (Experiment 4). This suggests that the engravings were part of a cultural practice—a style—in which they were reproduced, transmitted, and learned within a social group, as predicted by the H2.

Importantly, the engravings did not evolve over time to become easier to discriminate between the two archeological sites (Experiment 5; see also Experiment 4b in *SI Appendix*). This could indicate that the style-signifying elements found in Experiment 4 are an expression of passive rather than active style (33). That is, they evolved as a side effect of transmission and reproduction more than an explicit intention to communicate group identity, which would imply an effort to actively differentiate styles between groups. However, we note that the comparison between the engravings from Blombos and Diepkloof might not provide the best test case for this hypothesis. There is no direct evidence of contact between the groups inhabiting the different sites, which implies that the engraved patterns may have increased in discriminability relative to pattern production in neighboring groups from which we currently do not have archeological evidence (60). Furthermore, discriminability also depends on learning and might have been enhanced over time through extended exposure to the patterns irrespective of their changes in form (61, 62). In other words, while the engravings seem to evolve affordances for learning and transmission, pointing to their role in a cultural tradition of pattern production, it remains uncertain whether they functioned as explicit markers of group identity.

We found no evidence that the engraved patterns became increasingly discriminable within the two archeological sites. This suggests that the patterns were not under adaptive pressure to evolve affordances for a referential function linked to semantic contents as predicted by the H3. If the primary function of the engravings was to denote individual meanings in contexts of account holding or communicative exchange, there would possibly have been strong selection for optimizing the perceptual difference between individual forms in order not to confuse symbol meanings, as has been observed in other forms of notational practices (36, 63–65). However, we cannot exclude the possibility that early patterns already displayed high discriminability and therefore little room for development, and the relative discriminability of patterns could possibly depend on the size of the full repertoires (with large repertoires leaving less room for differentiation of individual signs), which in the case of the Blombos and Diepkloof engravings remains unknown. That is, while we do not observe any clear indications that the engravings served as denotational symbols in a fully developed system of referential signs, as predicted by the H3, there are also considerable sources of uncertainty that warrant caution (4, 7–9).

The experimental results reported here rely on contemporary human participants; this is a basic working condition if we want

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to leverage the power of tightly controlled experimental methods in the effort to understand the cognition of past humans (41–44). Human symbolic cognition critically depends on the functional wiring and connectivity of the brain, and it is difficult to investigate these functional levels of human cognition based on more traditional approaches such as morphological studies of artifacts, cranial casts, or genetic analyses (66). On the other hand, the archaeological record provides direct, material evidence for past behaviors that may potentially be bridged with underlying cognitive patterns through experimental work.

It would be useful to extend future experimental investigations to include a more diverse sample of participants, as it has been found that even low-level visual processes can present variability contingent on historical, demographic, and cultural factors (in particular literacy). This suggests that our cognitive systems are continuously being shaped by exposure to our cultural and environmental surroundings, potentially challenging grounding assumptions of our approach (67–69). However, it is also important to note that our experimental contrasts are all tested using a within-participant design and thus show the cognitive consequences of engravings spanning 30,000 y while holding constant any aspect of change to brain function.

Using experimentally derived measures of online human cognition, our findings inform discussions of the symbolic and cognitive function of ancient human artifacts. An advantage of our approach is that it requires the researcher to operationalize theoretically motivated hypotheses in concrete measurable variables and testable predictions. In the case of the Blombos and Diepkloof engravings, our findings lend support to certain interpretations in the literature while casting doubt on others. Not unlike manual tools, we suggest that the engravings evolved to become more effective "tools for the mind" as their producers became more skilled symbol makers (17, 19, 20). This implies that the changes observed are an expression of Middle Stone Age humans' increasing sensitivity to the potential cognitive consequences of their interventions in the material world, leading to cumulative refinements of those interventions. In the challenging pursuit of understanding human cognitive evolution, our approach and findings provide insights into critical cognitive parameters that cannot be achieved through the traditional methods of archeology and genetics, or by theoretical work alone.

Methods

Through all experiments we used outlines of the Blombos and Diepkloof engravings as stimuli. As we were interested in development of pattern composition over time, that is, how lines were organized in patterns and how these changed over time, we derived a controlled stimulus set consisting of 24 patterns (12 from Blombos and 12 from Diepkloof) that both closely resembled the originals in terms of compositional traits (e.g., line position and orientations) while maintaining number and length of lines constant (see Fig. 2 and *SI Appendix* for the full stimulus set and validation procedures). In all experiments (except Experiment 3) we ran additional experimental sessions using the 12 original outlines as stimuli to ensure that our observations were not an artifact of the controlled versions (*SI Appendix*).

The stimulus items were divided in three periods, early, intermediate, and late, corresponding to the classification used in Texier et al. (5). For the ochre engravings, these corresponds to the grouping presented in Henshilwood et al. (7), dating the early period engravings to approx 109 to 100 kya, the intermediate ones to approx 100 to 70 kya, and the late to approximately 70 to 52 kya. Given the uncertainty in the dating of the engravings, through all analyses period is treated as an ordinal variable which profiles the temporal order of individual patterns over the exact time spans separating them. Control analyses allowing temporal changes to vary by site are reported in *SI Appendix*. Stimuli presentation and response recording was carried out in PsychoPy2 (70). Statistical analyses were carried out in RStudio (71).

Experiment 1: Saliency. ***Participants.*** Seventy-one participants (36 female, 33 male, 2 other) with a mean age of 23.58 y (SD 3.49) took part in the experiment. Participants were recruited through the Cognition and Behavior Lab participant database and were mainly students studying at Aarhus University. The experiment was approved by the Human Subjects Committee of The Cognition and Behavior Lab, Aarhus University, and The Central Denmark Region Committee on Research Ethics. All participants signed informed written consent in correspondence to the local ethical regulations and were compensated with DKK 100 (∼$15) for their participation.

Apparatus and procedure. For stimulus presentation, we used a 19-inch cathode-ray tube (CRT) monitor and a mirror stereoscope at a viewing distance of 50 cm (*SI Appendix*, Fig. S3*A*). A standard color noise suppressor updated at a constant rate of 100 Hz was presented to the participant's dominant eye (*SI Appendix*, Fig. S3*B*). Targets were faded in in either the left or right visual field after a randomized delay of 0 to 400 ms and stayed on screen until a response was recorded, or a time-out occurred after 15 s. Participants were instructed to respond as soon as they could see the target by pressing the arrow key on the keyboard corresponding to the side of appearance of the target (left/right). The experiment proceeded through six repetitions of the 24 stimulus patterns, yielding in all 144 trials.

Analysis and results. Reaction times were modeled using a multilevel Bayesian Gamma regression model with a logarithmic link. In order to assess the likely factors influencing rate and shape, we used stacking weights based on leave-one-out cross-validation information criteria (see *SI Appendix* for details). A Gamma regression model conditioning both rate and shape on linear effects of period, stimuli, and participants was found most credible by model comparison. On average, earlier stimuli were identified in 2.27 s, intermediate stimuli in 2.03 s, and late ones in 1.82 s (Fig. 3*A* and *SI Appendix*, Table S2). Signal detection theory analyses of accuracy are reported in *SI Appendix*.

Experiment 2: Intentionality. ***Participants.*** Fifty-one participants (27 female, 21 male, 3 other) of mean age 23.2 y (SD 3.2) took part. All participants of Experiment 2 also took part in experiment one, that is, recruitment, ethical approvals, consent procedures, and compensation are identical to Experiment 1. Participants always completed Experiment 1 before Experiment 2.

Apparatus and procedure. Participants were seated at a standard Windows personal computer with a 22-inch liquid-crystal display screen. Through 276 trials, they were presented with pairwise combinations of stimulus patterns in randomized order. For each trial, participants indicated which of two competitor stimuli they found was more likely to have been intentionally produced by a human by pressing a key on the computer keyboard. The task was self-paced with no time-out.

Analysis and results. In order to assess whether patterns were perceived as more or less intentional, we modeled the data according to an outcome contest model (72):

$$\text{Judgment}_1 \approx \text{int}_{p1} - \text{int}_{p2},$$

where the likelihood function is a Bernoulli distribution, Judgment_1 indicates the log odds of choosing stimulus 1 as intentional when compared to stimulus 2, and int_{pn} is the estimated intentionality score a participant j perceives in a given stimulus n, that is, 1 or 2. Given two stimuli are simultaneously presented, the probability of choosing one over the other depends on their relative scores. int_{pn} is further defined, if linear effects of period are assumed, as

$$\text{int}_{pn} \approx a_{sn} + ß_p * \text{Period}$$

or otherwise as

$$\text{int}_{pn} \approx a_{sn} + ß_{1p} * \text{Period} + ß_{2p} * \text{Period}^2.$$

The best-performing model included a linear effect of time. The average early stimulus had a 18% and a 33% chance of being indicated as intentional, respectively, against a late and an intermediate stimulus. An average intermediate stimulus had a 33% and a 67% chance of being indicated as intentional, respectively, against a late and an early stimulus (Fig. 3*B* and *SI Appendix*, Table S3).

Experiment 3: Memorability. ***Participants.*** Seventy-five participants (45 female, 25 male, 5 other) of mean age 24.6 y (SD 4.4), different from the ones in Experiments 1 and 2, took part in the experiment. Recruitment, demographics, ethical approvals, and consent procedures are identical to Experiments 1 and 2. Participants were compensated with DKK 100 (∼$15) for their participation.

Apparatus and procedure. The computer setup was similar to Experiment 2. In each trial, participants were presented with a stimulus pattern for 3 s. Then, after a 2-s pause, the participant was instructed to reproduce the pattern as accurately as possible from memory by placing lines one by one and rotating them using the mouse. The experiment proceeded through 24 trials with patterns from the three periods presented in randomized order.

Analysis and results. The reproduction accuracy was calculated as the mean squared error (mse) in pixels between the bitmap image of the stimulus and the corresponding response bitmap screenshot:

$$mse = S\left(image_{stim} - image_{copy}\right)^2.$$

A lower number is indicative of lower reproduction error, that is, higher reproduction fidelity. The models were linear regressions following the same procedure as in previous experiments. A simple linear model with period as predictor was found most credible. The model indicates an average reduction in error of 0.05 per period, with early stimuli producing average errors of 0.71, intermediate ones of 0.64, and late ones of 0.59 (Fig. 3*C* and *SI Appendix*, Table S4).

Experiment 4: Cultural Traditions. ***Participants.*** Forty-two participants (27 female, 15 male) with a mean age of 25.7 y (SD 7.15), different from the ones in the previous experiments, took part in this experiment. Recruitment, demographics, ethical approvals, and consent procedures were identical to the previous experiments. Participants were compensated with DKK 50 (~ $7.50) for their participation.

Procedure and apparatus. The computer setup was similar to Experiments 2 and 3. In each trial, a target and two competitor stimuli (one from Blombos and one from Diepkloof) were presented on the screen. The task of the participant was to indicate if the target originated from the same site as the competitor to the left or right by pressing the corresponding arrow key on the keyboard. The experiment proceeded through 228 trials.

Analysis and results. We assessed participants' responses using a multilevel signal detection theory model (see *SI Appendix* for details). We assessed reaction times in correct trials using Gamma regression models. In order to account for the variation in similarity between pairs of competitor stimuli we added a random effect by stimulus pair. The remainder of the statistical procedure was analogous to the other experiments. We observed credible effects of period in the predicted directions. The models indicate an average increase in accuracy, as well as an average increase in the speed of accurate responses. In other words, stimuli from later times were easier to correctly match to stimuli from the same site than earlier ones (Fig. 3*D* and *SI Appendix*, Table S5).

Experiment 5: Discriminability. ***Participants.*** Fifty-seven participants (33 female, 24 male) of mean age 23.91 y (SD 4.75), different from the ones in the previous experiments, took part in this experiment. Recruitment, demographics, ethical approvals, and consent procedures were identical to the previous experiments. Participants were compensated with DKK 50 (~ $7.50) for their participation.

Procedure and apparatus. The computer setup was similar to the previous experiments. In each trial, the participant was presented with a target and two competitor stimuli. The target would be identical to one of the competitors, and the task was to indicate as fast as possible whether it was the left or right competitor by pressing the corresponding arrow key on the keyboard. To control for robustness of the discrimination, the target would either be presented at the same orientation or rotated 45° or 135° relative to the matching competitor pattern. The experiment proceeded through 396 trials.

Analysis and results. We assessed reaction times in correct trials using Gamma regression models. In order to account for the variation in similarity between pairs of stimuli we added a random effect by stimulus pair. The model did not indicate any credible effect of period on discriminability neither between nor within site, BF01 = 9.42, credibility = 90% (Fig. 3 *E* and *F* and *SI Appendix*, Table S9).

Data Availability. All data, code, and materials used in this project are available on the Open Science Framework (OSF) repository at https://osf.io/rbtk4/ (73).

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