

**Tracing the Lines: Empirical Approaches to Exploring Symbolically Mediated Social  
Behaviour in the Middle Stone Age**

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Dissertation in Language Sciences

## Abstract

This dissertation explores the social function of engravings found at the Blombos Cave and Diepkloof Rock Shelter archaeological sites dating to 70-100kya. I review the existing literature surrounding the purpose of these engravings, as well as previous empirical approaches to the transmission of Stone Age symbols and symbolic communication. Using a graphical iterated learning experiment, I tested if stylistic differentiation evolves under social pressure for group identification in such a way that facilitated novel observers' classifications of the symbols into their respective groups. My results show increased stylistic distinctiveness between groups, suggesting that stylistic features emerge in socially referential communication as identity markers. However, my findings align with those of Tylén, et al. (2020), suggesting that the Blombos and Diepkloof engravings passively evolved distinct styles rather than actively selecting them as markers of group identity. These results contribute to the broader understanding of cultural transmission and social behaviour, as well as support the integration of empirical approaches and archaeological investigation to present a more robust account of early symbolic communication.

*Keywords:* Social behaviour, cultural transmission, iterated learning, Middle Stone Age, style, group identity

## Introduction

Questions about language origins—and the origins of the necessary cognitive capacities which support language use—have been central to the interdisciplinary endeavour of language evolution research, an endeavour in which linguistics and cognitive science have historically played a crucial role. Many attempts have been made to determine the factors which led to language evolution, to no avail; the only consensus, it seems, is that there is likely some connection between cognitive evolution and linguistic evolution (Bickerton, 2007). Because human cognition does not fossilize, material artifacts have long been the main basis for any conclusions surrounding early language origins. The use of symbols—a kind of sign which has no natural or resembling connection with its referent, only a conventional one—indicates a shift in the way early humans understood themselves in relation to their environment and social group (Godfrey-Smith, 2014; Peirce, 1998). At that point, we see behaviourally modern humans who understand themselves as members of the groups of which they are a part, with material evidence taking shape as abstract symbols marked in shell or stone (Sterelny & Hiscock, 2014).

The presence of engraved patterns on ochre, bone, and ostrich eggshells in Middle Stone Age sites such as Blombos Cave and Diepkloof Rock Shelter suggests that early *Homo sapiens* engaged in some form of symbolic marking, though their function remains debated (Henshilwood et al., 2009; Texier et al., 2013). One prominent hypothesis is that these symbols served as markers of group identity. Symbolic group markers are well-documented in modern human societies, where cultural conventions and aesthetic traditions can signal membership and social affiliation (Tylén et al., 2020; Van Herk, 2012; Young, 2008). However, whether Middle Stone Age engravings were deliberately created to communicate group identity or whether their stylistic evolution was an incidental byproduct of cultural

transmission remains an open question. Addressing this issue is critical for understanding the cognitive and social foundations of early human communication and, by extension, the evolution of language.

My study builds on the empirical research of Tylén et al. (2020), specifically examining their cultural connotation hypothesis. This hypothesis proposes that the engravings found in the Blombos and Diepkloof caves functioned socially as markers of group identity. Drawing on experimental cultural evolution methods, I employ a graphical iterated learning paradigm to simulate how engravings might evolve as they are transmitted across generations. By examining whether engravings become increasingly distinct between groups when individuals are under pressures to identify with a certain social group, this study tests whether group-level stylistic differentiation could arise actively (as an intentional strategy) or passively (as a consequence of transmission biases). I highlight the necessity of incorporating empirical approaches into our exploration of early symbolic communication, as they allow researchers to explore operationalized hypotheses derived from the archaeological record.

I begin by reviewing the current archaeological evidence for the emergence of behaviourally modern symbolic communication, focusing on the Southern African Middle Stone Age. I will then present key research surrounding cognitive affordances in Stone Age tools and symbols, as well as graphical communication and iterated learning studies; this lays the foundation for the present study. I introduce my experimental methodology, which includes a graphical iterated learning task and a group discrimination task inspired by Tylén, et al. (2020). I discuss the implications of my findings in comparison with previous research and broader theories of symbolic communication and cultural transmission, and, finally, suggest avenues for future research.

## The Southern African Stone Age

The Southern African Middle Stone Age (300,000-2500BCE) has taken particular importance in the debate surrounding the origins of symbolic behaviour (Texier et al., 2013). Prior to the early 2000s, the consensus among researchers converged on an Upper Palaeolithic emergence of symbolically mediated behaviour, about 35kya. There were limited amounts of material artifacts attributed to *Homo sapiens* before 35kya, and the purposes of this evidence were highly contested. Some researchers claimed that these artifacts—which included beads, perforated and dyed shell fragments, and engraved bone dating from 50 to 90kya—were clear evidence for symbolically motivated behaviour before the Upper Palaeolithic era. Others argued that the marks and patterns on the artifacts were natural or not intentional; even if the shell and bone were marked with intention, they do not demonstrate the systematic patterning expected of symbolic behaviour (Henshilwood et al., 2002, 2009).

Evidence found in the following years suggested that symbolically-mediated behaviours were integral to early human behaviour during the Middle Stone Age, about 35-50ky earlier than previously thought (Henshilwood et al., 2009). Archaeological evidence suggests a high degree of cultural development during that period, manifesting itself as symbolic communication (Tobias, 2005). Some of the most notable sets of artifacts include engraved ochre pieces from the Blombos Cave site and engraved ostrich eggshell fragments from the Diepkloof Rock Shelter site. Christopher Henshilwood (2003, 2009, 2011) and Pierre-Jean Texier (2010, 2013) have written the dominant portion of the influential literature on the Blombos and Diepkloof sites, respectively. The following sections describe the two sites in further detail and overview the competing theories surrounding the intentionality and use of these engravings and associated artifacts. I argue that observations from these artifacts

are insufficient evidence on which to draw any conclusion about the nature of these artifacts as markers of symbolic communication.

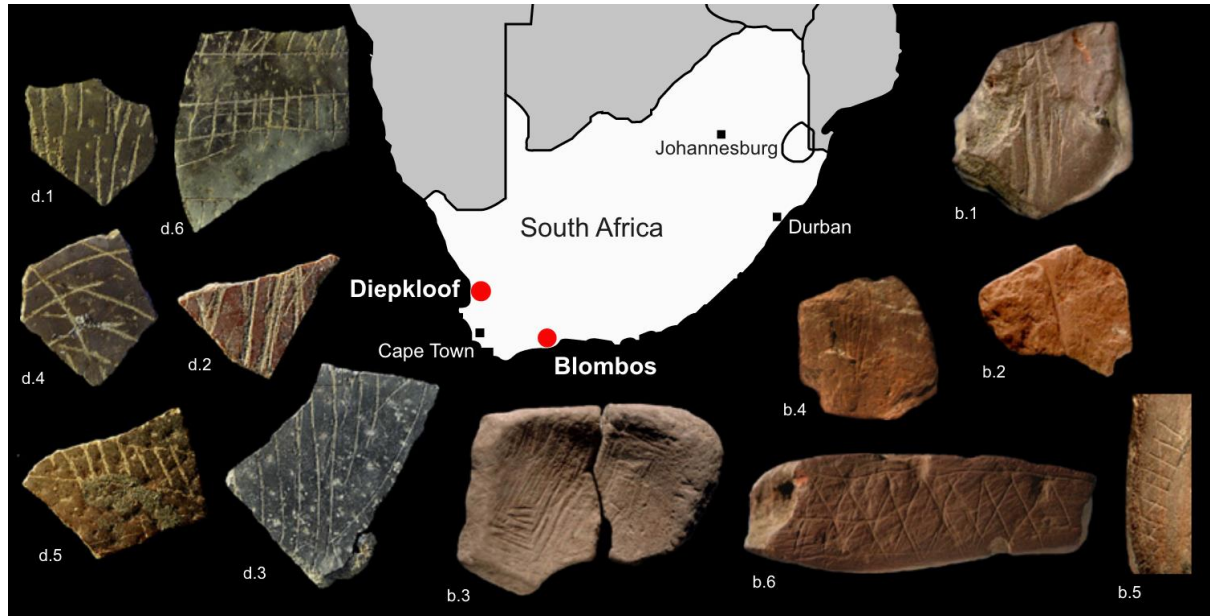


Figure 1: A map of present-day South Africa indicating the location of the Blombos and Diepkloof sites, as well as sample artifacts from each site. Artifacts from Blombos are marked with (b); artifacts from Diepkloof are marked with (d). From Tylén, et al. (2020).

## Blombos Cave

Located in Southern Africa, the Blombos Cave holds what appears to be an ochre-processing workshop dating back to 100kya (thousand years ago) (Henshilwood et al., 2011). Within this archaeological site, Henshilwood and his collaborators found pieces of shell engraved with ochre dating between 100-75kya. Different ages of engravings were characterized by unique stylistic motifs, including parallel and crosshatched lines. Based on the attention required to create marks with the consistency and depth of those observed in the Blombos engravings, researchers have concluded that the engravings and motifs were deliberately created but were not immediately recognizable as being discrete patterns which were differentiable from other discrete patterns. (Henshilwood et al., 2009).

The methods by which the ochre and engravings were likely created demonstrate that these Middle Stone Age humans who inhabited the Blombos site possessed the conceptual ability for focused attention and long-term planning. The manufacture of ochre dye requires tool use to knap and crush stone into a powder, and there is evidence that other minerals like charcoal were added to the mix to create colour variations. The engravings required that the engraver use a pointed tool repeatedly in the same place with the same motion; the regularity and profile of the engraved lines cannot be made accidentally or absent-mindedly (Henshilwood et al., 2009, 2011).

### **Diepkloof Rock Shelter**

About 400km from the Blombos site sits the Diepkloof Rock Shelter, another Middle Stone Age archaeological site boasting a collection of potentially symbolic artifacts. More than 80 fragments of ostrich eggshell, likely used as liquid containers, engraved with several variations of geometric patterns found at the site have been aged to between 85-52kya (Parkington, 2005). While the patterns varied across individual pieces and timeframes, researchers never encountered one piece with multiple motifs (Texier et al., 2013). Hatched band and sub-parallel line patterns were the most notable motifs, similar to those found at the Blombos Cave.

It is likely that the engravings on the ostrich shell liquid containers were created by the same methods demonstrated at the Blombos site. The required focused attention and long-term planning would have also been observable in this population (Texier et al., 2013).

### **Theories of purpose**

The intended purpose or symbolic meaning of Middle Stone Age engravings like those found at Blombos and Diepkloof have been hotly debated. Many researchers agree that these engravings were the result of deliberate manufacture. Some, like Henshilwood (2002),

find the engravings to be definitive evidence of cultural modernity, fully developed symbolic communication, and even syntactical language emerging during the Middle Stone Age. Many others, such as Parkington (2005) have questioned such far-reaching conclusions, claiming that these engravings were merely aesthetic, if there was any purpose behind their manufacture at all (Tobias, 2005). These conclusions are based on the notion that there is a lack of sufficient evidence in the archaeological record alone to ascertain if the engravings served a symbolic or social function; without any insight into the social environment of the inhabitants of the Blombos and Diepkloof sites, it is impossible to know the role of the engravings in a social context.

From the archaeological evidence and the suggestion that the engravings were deliberate, Henshilwood and his collaborators suggest that the motifs at Blombos may have been made with symbolic or denotational intent (Henshilwood et al., 2002). The Blombos engravings do not demonstrate the degree of standardization typically observed in symbolic systems. Despite this, Henshilwood et al. claim that a “sufficient case can be made that some of the engraved pieces were perceived as symbolic” (pp.43), claiming that four distinct categories of patterns can be distinguished among the samples and that there would have been a high colour contrast between the red ochre incisions and the dark background of the pieces when they were freshly made (Henshilwood et al., 2009). I see the evidence as supporting an understanding of the engravings as aesthetically resonant, but conclusions about the symbolism or denotation of these ochre pieces are unsubstantiated by Henshilwood et al.’s observations. In order for the case to be as sufficient as Henshilwood claims based solely on material artifacts, we would expect to see a higher degree of standardization among the motifs, which would be more immediately recognizable as a symbolic system. As it stands, more evidence is needed to substantiate the claim that the ochre pieces served a symbolic function.

Is it possible that these engravings served an intermediate purpose as symbolic, but not fully denotational, markers of social communication? Geometric and iconographic representations serve as powerful evidence for the emergence of symbolically mediated behaviour. The production and use of symbols code information to be shared with other members of the social group, drawing on the pre-existence of social and cultural identities. Current theories suggest that the humans of the Middle Stone Age, at least in Southern Africa, lived in a world characterized by symbolically mediated social and cultural relationships. These symbols were culturally transmitted, indicated by the distinct and consistent artifact styles which change over time (Henshilwood et al., 2009; Henshilwood & Marean, 2003; Texier et al., 2013). It is possible that the use and transmission of these symbols served as expressions of group identity, in both intra- and inter-group contexts (Texier et al., 2013).

Texier and his collaborators (2013) note the use of the engravings on functional objects at Diepkloof, which indicate that the Diepkloof inhabitants were interacting with the engravings in the same social and structural way they would have interacted with the eggshell containers. According to Texier et al. (2013), the engravings likely served an important role in information transmission, or portrayal of individual or group identity in both a functional and symbolic context. They base this assertion on well-established evidence that ostrich shells were used among Middle Stone Age populations to carry water; they extend the social embeddedness of this action to suggest that these populations were maintaining domestic spaces, creating aesthetically meaningful artifacts, and understanding and portraying themselves as social beings (Parkington, 2005; Texier et al., 2013).

Any conclusion drawn about the nature of the engravings, and the subsequent extension of these conclusions to inform theories about the emergence and evolution of human communicative behaviour, is tenuous (Henshilwood & Marean, 2003). Theories

remain speculative and rely heavily on the analyses of material artifacts alone (Wisher & Tylén, 2024). These conclusions are merely extrapolations, suggesting that the engravings extend into social practices insofar as they are associated with objects which are thought to have served a social purpose. I afford credence to the theory that the engravings were purposefully created and served an aesthetic function; however, to explore further into the true purpose of the engravings from a social or symbolic stance, and what these roles mean for our understanding of social and linguistic development, it would serve us to simulate the development and transmission of the engravings under certain social or symbolic pressures.

## **Empirical approaches**

### **An integrative approach to symbolic evolution**

Experimental studies concerning the emergence of symbolic behaviour have been historically disconnected from anthropological and archaeological fields. Empirical exploration using modern humans has proved informative in this debate, providing evidence for the dynamic cognitive processes on which symbolically mediated behaviour was built. Wisher and Tylén (2024) propose that, in order to build a robust model of early symbolic evolution, researchers should use experimental methods to understand the various *cognitive affordances* (the way properties of artifacts scaffold aspects of cognitive processing) of Stone Age patterns and symbols. These experiments use material artifacts from the archaeological record as stimuli for controlled experiments. These methods integrate insights from both cognitive sciences and archaeology to build a robust model of the emergence of symbolic behaviour.

These integrative approaches pose numerous benefits to our understanding of the purpose served by past symbolic artifacts. Experimental methods allow researchers to test concrete hypotheses about underlying mechanisms of cognitive behaviour, leading to strong

claims rather than mere speculation. Experimental extensions also provide sizable amounts of data for quantitative analysis, furthering the foundation on which the empirical claims sit. They are particularly valuable for understanding cultural transmission, as they allow us to simulate real-time social dynamics and empirically test assumptions about social transmission.

In these experiments, it is assumed that the cognition of contemporary humans maps onto the cognition of past humans in a way which allows us to draw comparisons about their cognitive functions. This is a widely accepted assumption; there is no evidence that hominid brain anatomy has changed in any major ways over the past 250ky, meaning the underlying cognitive architecture has likely remained consistent (Tattersall, 2017). Additionally, studies show that humans have similar visual and perceptive tendencies to farther removed ancestors—primates—indicating that anatomically modern humans from the Middle Stone Age had equally, if not more, similar cognitive systems (Wisher & Tylén, 2024). Given the evidence for toolmaking and other crafting behaviours as far as 2.5mya (Morgan et al., 2015) and the relatively similar cognitive capacities between humans and primates, I agree that, while the modern human participants are not completely analogous to Middle Stone Age humans, contemporary experiments likely give an informative insight into the behaviours of early humans living 100-50kya.

This section gives an overview of exemplary experimental studies published in this area, including Morgan, et al.'s 2015 study about hominin toolmaking and teaching and Tylén, et al.'s 2020 study surrounding symbolic behaviour evident in the Blombos and Diepkloof archaeological records. The present study is introduced, which builds from Tylén, et al.'s (2020) cultural connotation hypothesis and incorporates Morgan, et al.'s (2015) method of adding pressures for specific transmission methods, as well as iterated learning

paradigms and graphical communication tasks like those used in studies by Caldwell and Smith (2012) and Tamariz and Kirby (2015).

### **Morgan, et al. (2015): Lithic toolmaking and social transmission**

Many of the studies into this subject use lithic tool production as an exemplary case of cultural transmission. Morgan, et al. (2015) conducted a large-scale experimental study testing the efficacy of five social learning mechanisms for transmitting Oldowan stone knapping techniques. The Oldowan technocomplex is associated with the production of sharp flakes from a stone core by striking the core with a hammerstone, which archaeological evidence suggests was a widespread skill among early hominins around 2.5mya. The complexity of this toolmaking process suggests that it was socially learned and required considerable practice, and regional variations in flake shape further substantiate this notion.

Noting that previous studies into lithic toolmaking had been largely theoretical or abstract in nature, Morgan, et al. (2015) sought to investigate the social transmission of toolmaking skills. They did so by having participants learn stone knapping techniques via five different learning and teaching mechanisms, measuring the relative rates of transmission resulting from each mechanism. The mechanisms were as follows:

- Reverse engineering (pupil sees flakes created by tutor, but not the tutor themselves)
- Imitation/emulation (pupil watches tutor and imitates their behaviour)
- Basic teaching (pupil imitates tutor, tutor can interact with pupil's hand placement)
- Gestural teaching (pupils and tutors could interact using any physical gesture)
- Verbal teaching (pupils and tutors could also communicate verbally)

Morgan, et al. (2015) found that the social transmission of lithic stone knapping skills was facilitated by teaching and verbal communication. There is little evidence that imitation and emulation enhanced the speed and success of skill transmission. Their results suggest that

high-fidelity social mechanisms, like gestural and verbal teaching, vastly improve the speed and accuracy with which new learners reach competence in stone knapping skills. Though this study focuses on toolmaking rather than symbol transmission, an analogy can be drawn between the two non-linguistic, socially transmitted practices.

Placing participants into these *what-if* scenarios effectively asks the question, “what would happen if a certain social transmission method was used to pass on the Oldowan technocomplex?” These scenarios do not make definitive claims about the mechanisms that governed the transmission of the Oldowan technocomplex 2.5 million years ago. However, they illustrate the types of evidence we might seek in the archaeological record to support hypotheses about social and cultural behaviour during this period. Morgan, et al.’s (2015) study is an exemplary case of contemporary human trials, allowing researchers to simulate patterns of social transmission to inform conclusions about cognitive affordances available in the artifacts of our early ancestors.

### **Tylén, et al. (2020): Understanding the evolution of symbolic behaviour at Blombos Cave and Diepkloof Rock Shelter**

As noted in the Introduction, there have been competing accounts surrounding the nature of the Blombos and Diepkloof engravings. The sparse archaeological records have made any conclusions, especially those relating to the evolution of social and linguistic systems, tenuous. Noting that few empirical studies had been done into the symbolic nature of early engravings, Tylén, et al. (2020) operationalized the contested hypotheses (outlined below), assuming that different symbolic functions are associated with different measurable cognitive affordances.

Despite the differences in material and lack of direct evidence suggesting that the inhabitants of Blombos and Diepkloof interacted with each other, there are striking similarities between the composition and development of the engraved patterns between the

two sites (Tylén et al., 2020). The engravings also demonstrate similar compositions, namely line quantity, depth of engraving, and crosshatching patterns. The archaeological record of the two sites each demonstrate potentially symbolic artifacts spanning 30ky, meaning these artifacts developed at the same site and likely by the same lineage of inhabitants. This makes the two archaeological records an intriguing case to study individually and in comparison to each other. To empirically test the two archaeological records, Tylén, et al. (2020) derived a corpus of controlled stimuli from the published pattern outlines, which retained the original patterns from the engravings from each site while holding parameters of line number and length constant (see Fig. 2). Using this derived corpus, Tylén, et al. (2015) explored three main hypotheses: the aesthetic resonance hypothesis, the symbolic denotation hypothesis, and the cultural connotation hypothesis.

The stimuli represented three stages of evolutionary trajectory, corresponding to the early, intermediate, and late stages of the relevant archaeological record (see Section 3 for example). This allowed the researchers to draw conclusions about change within groups over time, as well as between groups. The stimuli were derived from outlines of the published photos of the engravings, with line numeracy and length standardized. Each final stimulus had six lines of equal length, with their orientation matching that which was found at their corresponding location and time period (Tylén et al., 2020).

Tylén, et al. (2020) operationalized and tested three different hypotheses. The aesthetic resonance hypothesis claims that the engravings were produced for aesthetic appreciation and served no further purposes as a symbolic communication system. On this account, the engravings serve as nonreferential but visually pleasing marks. It was predicted that, as humans became more skilled at making aesthetically pleasing patterns, the engravings would become more perceptually salient to the human eye. To test this hypothesis, participants took part in continuous flash suppression trials, a technique in which a

participant is presented an image (in this case, the engraving) to one eye and a continuous dynamic stimulus (such as flashing coloured lights) to the other. The goal of this method is to suppress conscious awareness of the image and reveal insights about how the image is processed when unconsciously perceived. The results of these trials revealed that the engravings became more perceptually salient as a function of period, as later patterns were recognized faster than earlier ones. Participants also agreed that later patterns were more likely to be intentionally made than earlier patterns. Tylén, et al. concluded that the engravings from the Blombos and Diepkloof sites became increasingly salient to the visual system over this period of evolution.

The symbolic denotation hypothesis tests the other end of the symbolic spectrum, investigating if there is evidence that the engravings served as fully symbolic denotational systems. On this view, the symbols would have functioned as referential signs, indicating that these early humans had representative patterns akin to glyphs or words. Patterns would have been optimized over time for discriminability between individual signs. This was operationalized using a forced-choice discrimination task wherein participants selected which one of two choices corresponded more closely with a target pattern. The data do not suggest that the individual signs from the same site became more discriminable over time, and therefore it is unlikely that the engravings found at the Blombos and Diepkloof sites served as fully denotational systems (Tylén et al., 2020).

Finally, the cultural connotation hypothesis holds that the engravings served a social function as markers of group identity. Systematic stylistic variation and development has been observed in these sets of engravings, but speculation remains about the extent to which these motifs were interpreted as stylistically similar, if style developed actively or passively over time, or if the stylistic systems served as explicit markers of group identity. The idea here is that, if the Blombos and Diepkloof drawings served as markers of group affiliation,

then the data drawn from the experiment will suggest that the drawings became easier to recognize as belonging to one of the two sites, and observers will be quicker to discriminate engravings belonging to different sites than those belonging to the same site (Tylén et al., 2020).

The experiment testing this hypothesis was executed in two parts. Both tasks involved forced-choice discrimination tasks, similar to those used in the symbolic denotation investigation. For the first task, participants were asked to match one of two engravings with a sample engraving, insofar as they believed the selected engraving and the example were from the same cave. Response accuracy increased as a function of period, indicating that site-specific styles evolved over time, which made it easier for novel viewers to pin patterns to a specific site given an example (Tylén et al., 2020).

The second task asked participants to discriminate an ‘odd one out’ in the same setup, this time measuring for speed. Based on the results of this experiment, participants took much longer discriminating group membership without specific ‘correct’ examples. This indicates that between-group discriminability did not improve over time, and that the engravings found at the Blombos and Diepkloof sites did not serve as actively created, explicit markers of group identity (Tylén et al., 2020). The two phases of this experiment are measuring slightly different effects. The first phase measured the development of stylistically salient features in each group over time; the second measured how successfully novel viewers could discriminate the engravings belonging to one site from the engravings belonging to the other.

In summary, Tylén, et al.’s (2020) study found evidence that the engravings served aesthetic purposes and were unlikely to have served as denotational symbolic signs, but ambiguity remained regarding their social function as markers of group identity. The social function of these symbols is the most relevant to my study. Were they active markers of group identity, created by members of a population to communicate group membership

within and outside of their social group, or did style develop merely as a passive trait of cultural transmission? Tylén, et al. (2020) claim that there is strong evidence for the passive development of group style as a result of social transmission, but this development was not driven by an explicit desire to communicate group membership. Using further empirical strategies to expand on this ambiguity could offer further insight into the social function of symbols like those from the Blombos and Diepkloof sites.

### **Graphical communication task and iterated learning experiments**

The iterated learning model is an emergent experimental paradigm for investigating the relationship between cultural transmission and language evolution (see e.g. Brighton, 2005; Kirby, Cornish, & Smith, 2008; Smith, 2003, 2022). Iterated learning is described as the process by which one individual's competence is acquired on the basis of another individual's behaviour, which they in turn acquired in the same way (Smith et al., 2003). In other words, the model assumes that languages develop and persist through a cycle of learning and use, sometimes called a diffusion chain (Smith, 2022). The underlying mechanisms which drive these properties are often cited to be pressures on the learnability and expressivity of language.

Iterated learning models have also been used to investigate the features of cognition and sociality which give rise to the cycle of learning and use in graphical symbols. I will outline two types of graphical communication studies—referential and non-referential—which focus on distinct aspects of learning and use in graphical symbols. Given that the referential focus of my study falls somewhat in between these two, I find both to be informative inspiration for the methods of my study as well as interpretation of the results.

In their 2015 study, Tamariz and Kirby used non-referential (meaningless) drawings as stimuli in a graphical learning experiment which explored the relationship between

learning and compressibility, a process by which cultural information, such as symbols, become less complex. The study involved a diffusion chain of participants replicating a non-referential drawing, wherein each participant aimed to replicate the drawing created by the previous participant. By manipulating the presence of learning or replication down a diffusion chain, they found that without pressure for learning, illustrations retain their complexity and arbitrariness along the diffusion chain.

Their study used two conditions. The Memory condition removed the model illustration from the participant's view before they tried to replicate the model. This required that the participant learn salient features about the target drawing and retain them for a short period of time. Illustrations made under the Memory condition demonstrated compression over time, making the drawings simpler and more standardized as they moved through the generations. Alternatively, the model remained visible to the participant during the Copy condition. The Copy condition exerted no pressure on participants to learn elements of the model for reproduction, and the original complexity remained over iterations. The Copy condition also resulted in random innovations, which came about in an unbiased way and were retained across generations.

To measure the complexity of the drawings over time, Tamariz and Kirby (2015) measured the perimetric complexity of digitizations of each of the drawings. Perimetric complexity is a mathematical measure which captures how convoluted a figure is based on the perimeter of the figure and its ink area; that is, a measure of roughly how 'complex' a figure may appear to a human observer, irrespective of the size of the illustration (Pelli et al., 2006). Tamariz and Kirby (2015) found that perimetric complexity measures significantly decreased over the Memory condition, more so than over the Copy condition. They attribute this pattern to the learning required of the participants under the Memory condition, where only the most perceptually salient features of the model drawing were stored in the short-term

memory for replication. This was not required of the participants under the Copy task. Therefore, there is evidence that the compressibility of symbols comes as a result of pressures for learnability across a cultural transmission chain.

Graphical communication tasks can also be used to explore the evolution of conventionality of referential symbols as a result of cumulative cultural evolution. Caldwell and Smith (2012) conducted a graphical communication study to investigate if members of small social groups (microsocieties) would adopt conventional signs for communication, even as naïve members were added to the group. Their study builds from that of Garrod, et al. (2010), which used a *Pictionary*-like task to explore the role of social grounding and feedback in the evolution of conventionality of symbolic communication. The main variable manipulated in this study was the interaction, or lack thereof, with the intended recipient of the communication. In this study, participants played a game similar to *Pictionary* under two conditions. In the first—the Interactive condition—matched pairs played the game six times back and forth. The second condition—the Chain condition—involved six iterations of a diffusion chain. Their main conclusions focused on the improvement of successful referent matching under the Interactive condition, which they cite as the effect of social grounding between interacting groups. The complexity of referential symbols decreased in the Interaction condition, while it remained the same or even increased across the Chain condition.

Caldwell and Smith (2012) adopted a ‘replacement microsociey’ paradigm to extend Garrod, et al.’s (2010) study. This paradigm allowed the authors to investigate if the evolution of the referential symbols was truly cultural, meaning it remained consistent even as group membership changed. One member of the group acted as the drawer, trying to graphically communicate a colour word to their microsociey using a black pen and white paper. Once the group agreed on a meaning, one participant made a response on behalf of the

group, and the drawer was replaced by a new member. The next most ‘experienced’ member of the group became the drawer, and this task continued six times. As a result, the symbols for each colour word became more conventional. New members were able to learn the association between the colour word and the conventional symbol successfully through interaction with the group.

Caldwell and Smith (2012) also used perimetric complexity measures to assess the movement towards conventionality across the experimental task, as well as timed trials to measure communicative efficiency. They found that the signs became simpler and more conventional across generations, pointing to cumulative cultural evolution of the signs based on grounding with the relevant social audience.

### **Motivations**

As shown in the previous section, models of simulated social pressures and iterated learning offer experimental avenues of exploring the dynamics of the social transmission of symbolic systems. Combined with Wisher and Tylén’s (2024) notion of general cognitive affordances, these models could give valuable insight into the social and communicative dynamics at play during the creation and use of Middle Stone Age engravings, like those found at the Blombos and Diepkloof sites.

The present study extends the empirical research done by Tylén, et al., focusing on their cultural connotation hypothesis. The cultural connotation hypothesis suggests that the engravings found in the Blombos and Diepkloof caves served a social function as markers of group identity. Though there is no direct evidence suggesting that the two groups interacted, there are similarities in both the composition and evolution of the groups’ engravings, making them an interesting (though imperfect) test case for this hypothesis (Tylén et al., 2020). The new paradigm, further explained in the proceeding section, uses the stimulus from

the Blombos and Diepkloof sites to begin a graphical iterated learning experiment wherein participants are incentivized to communicate group membership.

The iterated learning paradigm assumes that any behaviour which is culturally transmitted must encode enough information so that the behaviour survives over time (Brighton et al., 2005). In this study, participants are introduced to both horizontal and vertical stimuli (engravings from the previous generation and current generation were shown at once, indistinguishable to the participant). This is more analogous to the way engravings would have been transmitted in social groups, with individuals learning from both previous generations and their own peers. By replicating the process of cultural transmission, the present study sheds light on the evidence for this mechanism found in the Blombos and Diepkloof engravings.

By introducing explicit pressures for group identification in a graphical communication task, the present study provides insight into what results one would expect if there were certainly pressures on Middle Stone Age humans for group identification of this kind. This reflects the methods of Morgan, et al.'s (2015) study by introducing a *what-if* scenario wherein the cave inhabitants were intentionally using engravings for the purposes of social differentiation. As noted earlier, these experimental designs and results will not directly map onto the hypotheses and data used by Tylén, et al. (2020), and, by extension, the present study. Tamariz and Kirby (2015) focus on learning in non-referential signs; Caldwell and Smith (2012) explore social grounding and conventionality using referential signs. Symbols communicating social identity would be 'semi-referential', and I expect to see observations from both types of tasks reflected in my study.

Despite their differences, these studies show that graphical communication experiments are informative in regard to their hypotheses. When exploring the possible social functions of the engravings found at the Blombos and Diepkloof sites, I adopt a similar

graphical communication task and measures of communicative efficacy and complexity. When compared with the results of Tylén, et al.'s (2020) study using, the insights from the data will expand the evidence we can consider when determining the presence and intentionality of social communication at the Blombos and Diepkloof sites.

## **Methods**

This experiment aims to investigate whether engravings, such as those found in the Diepkloof and Blombos caves, could have evolved over time to reflect intentional group identity differentiation, assessing if stylistic features develop across generations to enhance intergroup discriminability as a form of symbolic communication. The following experiment assesses this hypothesis through a two-part experiment. The first part (Iteration) uses an iterated learning paradigm to simulate the transmission and replication of engravings across generations, thereby creating the stimuli for the second part (Discrimination). The Discrimination task assesses the level of discriminability between the two groups based on the engravings they create, as well as if discrimination improves between later generations as compared to earlier ones. This task follows from Tylén et al.'s (2020) task, testing the discriminability between groups without examples, but measures the rate of successful discrimination rather than the speed of discrimination. Prior to data collection, the designs and procedures of both parts of this study received ethical approval from the PPLS Research Ethics Committee at the University of Edinburgh.

### **Part 1 – Iteration**

***Procedure and materials.*** The Iteration task used the stimulus set used by Tylén, et. al. (2020, see Figure 2) in their series of experiments exploring the potential of the Blombos and

Diepkloof engravings to denote aesthetic, cultural, or symbolic meanings. The initial stimulus (Figure 3) came from the ‘early’ collection of engravings, with the first participant being shown eight engravings taken from the original archaeological sites: four corresponding to the Blombos cave (in this case, Cave A) and four corresponding to the Diepkloof cave (Cave B). These items were approximated by the researcher on pieces of paper and demonstrated to the participant in grids on a table. The stimuli remained in full view of both the participant and researcher for the duration of the task.

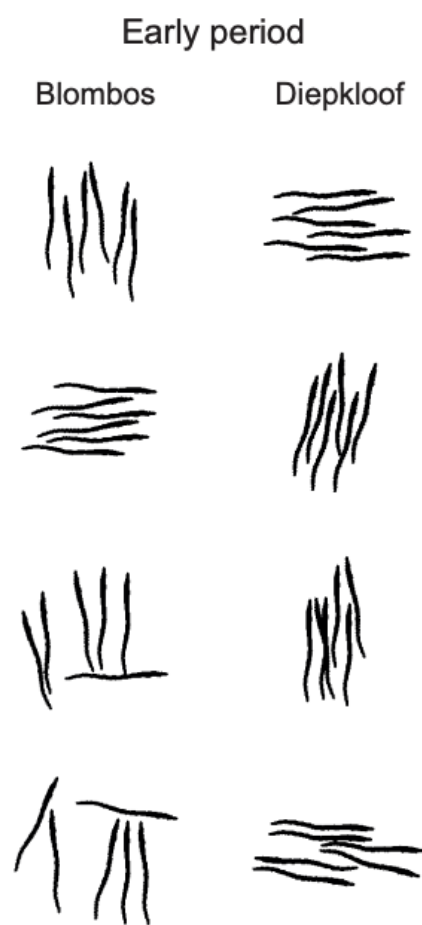


Figure 2: 'Early' period data approximated from the Blombos Cave (right column) and the Diepkloof Rock Shelter (left column), used in the Tylén, et al. study (Tylén, et al., 2020, Supplementary Information).

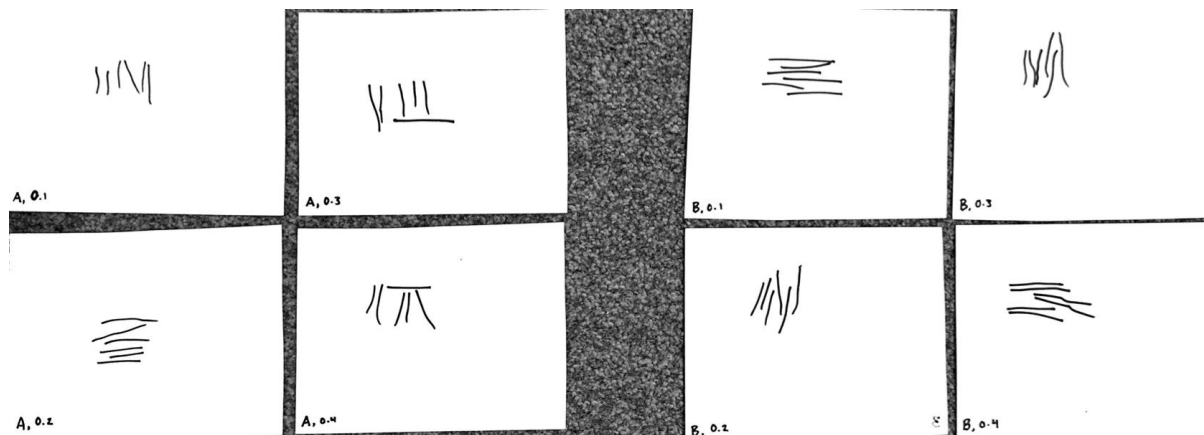


Figure 3: The initial stimulus shown to Participant 1, based on the 'Early' period data in Figure 2. Engravings on the right correspond to Cave A (labelled A.0-), and those on the left correspond to Cave B (labelled B.0-). Labels were added post-study for demonstration purposes.

To begin the Iteration task, the participant was given an incentive by the researcher to identify with either Cave A or Cave B. Participants were told to identify strongly with either Cave A or B (their affiliation was decided by the researcher) and to avoid their person or items being associated with the other Cave. The participant was then asked to illustrate an 'engraving' on a piece of paper that would be identified as an engraving from their Cave and not the opposing Cave. If the participant asked for further information, they were simply told to focus on the features of the drawings and to keep it simple.

Following the completion of the task, the participant's illustration then replaced one item in the stimuli set shown to the next participant, meaning Participant 2 would see seven illustrations from Generation 0 and one illustration from Generation 1 (Figure 4). The Iteration task was completed 16 times, simulating a complete replacement of the stimulus set two times; eight participants identified with Cave A, and eight with Cave B.

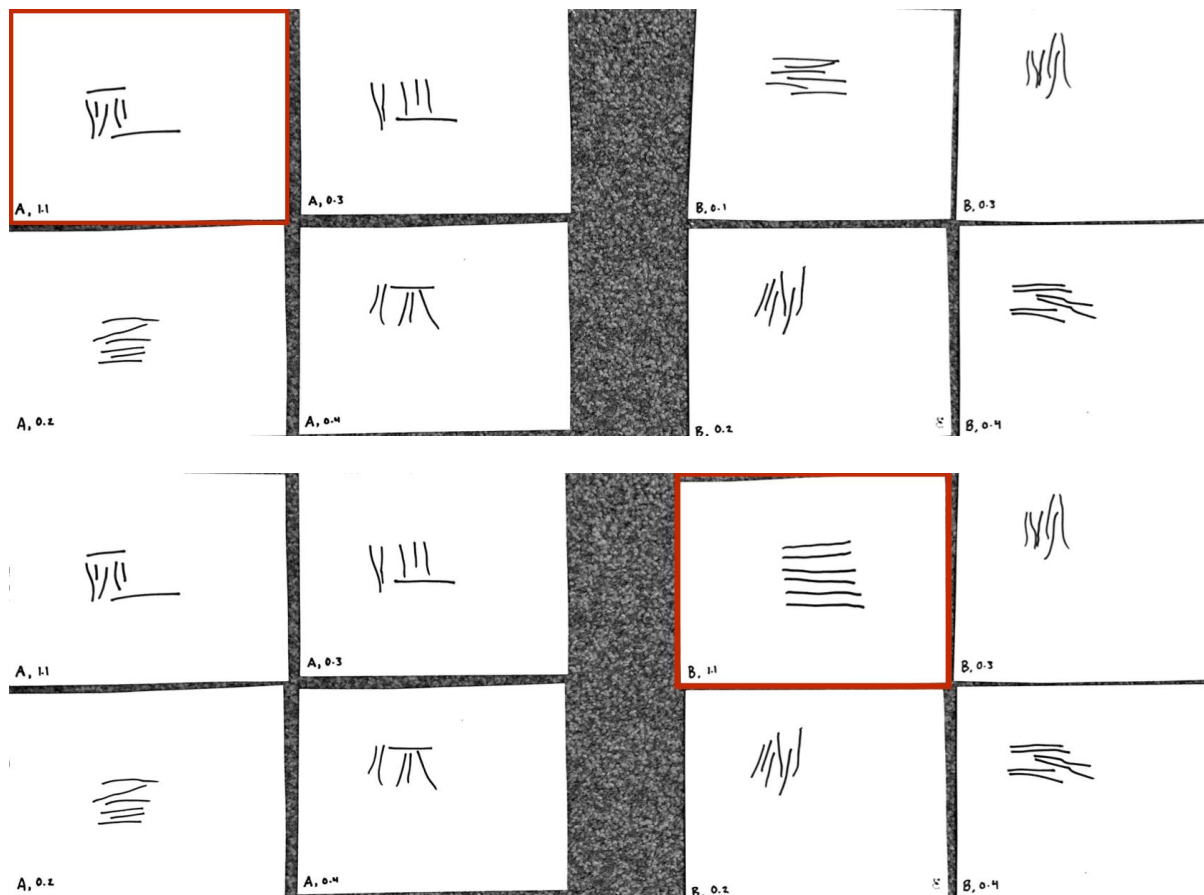


Figure 4: An example of the stimulus shown to Participants 3 and 4. Red outlines indicate the engraving replaced before the trial. This process alternated between Cave A and Cave B over two entire replacements.

**Participants.** 16 participants took part in the Iteration task. Each of them was an undergraduate student at the University of Edinburgh at the time of the study. These participants were recruited through social media and by word of mouth.

## Part 2 – Discrimination

The Discrimination task tests the hypothesis that, given that the engravings from the Iteration task were generated with explicit pressure for group identification, the engravings belonging to the two Caves are discriminable from each other and will become more discriminable over generational development.

**Procedure and materials.** Following the completion of the Iteration phase, there were 24 illustrations generated over three generations. Generation 0 corresponds to the initial stimuli,

with Generation 1 and Generation 2 describing the illustrations created by the participants of the Iteration task. The digitized engravings were printed and labelled to reflect their association with Cave A or Cave B, as well as their generational association (Initial, Generation 1, or Generation 2). These labels were only made known to the researcher.

To begin the Discrimination task, each participant was asked to complete three sorting tasks in succession. The participant was shown eight illustrations—the initial stimuli, belonging to Generation 0—which were novel to the participant. The researcher then asked the participant to sort the illustrations into two groups. Once the participant was satisfied with their groupings, they repeated the task twice more with the illustrations from Generation 1 and Generation 2. The complete groupings from each participant were photographed for data collection and analysis.

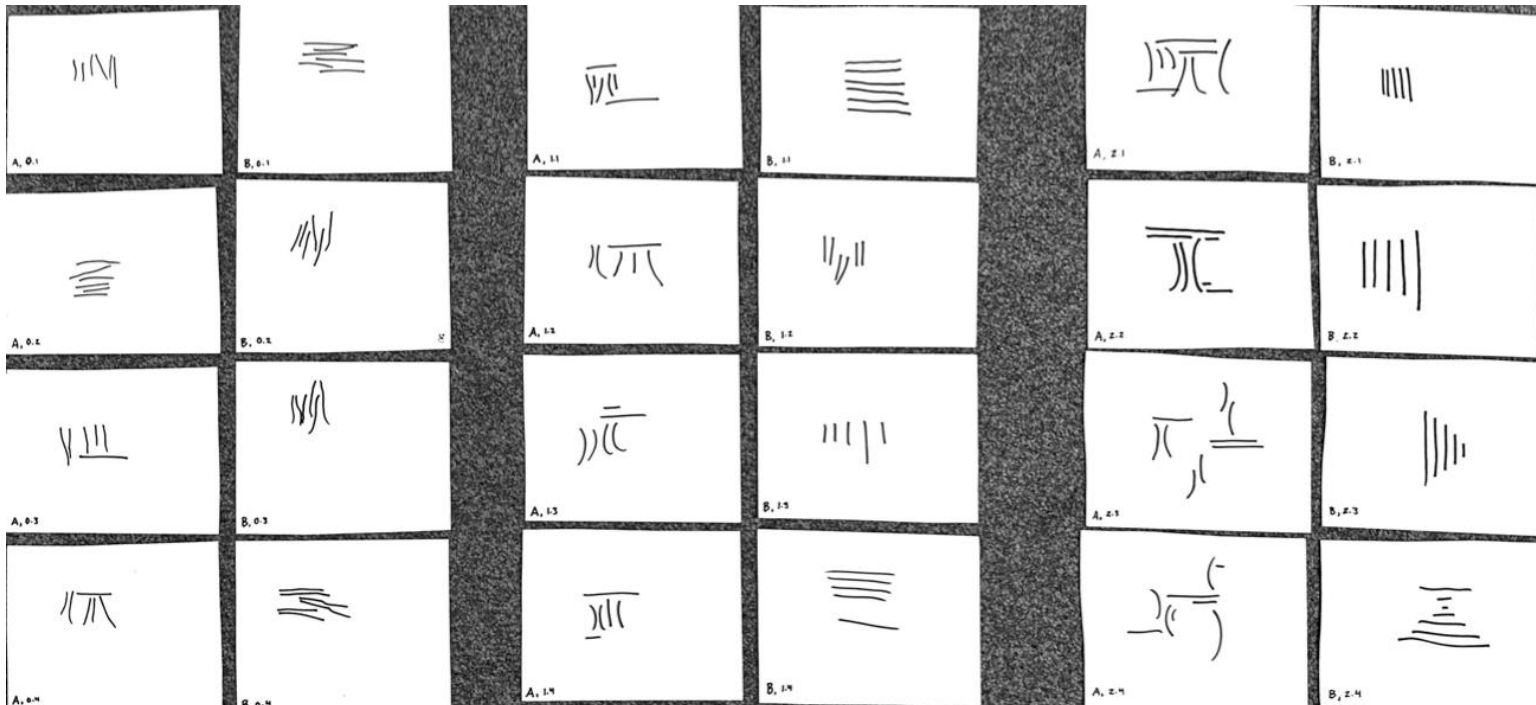
***Participants.*** Eight participants took part in the Discrimination task. Each of them was an undergraduate student at the University of Edinburgh at the time of the study. These participants were recruited through social media and by word of mouth.

## 2. Results

Figure 5: The complete set of engravings upon completion of the Iteration Task, organized by Cave (A to the right, B to the left) and Generation (left to right: 0, 1, 2).

### Rates of successful between-group discrimination

The data show a trend indicating that the engravings become easier to discriminate between the two sites. The mean rate of successful sorting increased from 82.5% for Generation 0 to 100% for Generations 1 and 2 (see Figure 6). A paired t-test showed that the difference in the mean success rate between Generation 0 and Generation 1 was marginal in regard to statistical significance ( $t(7) = -2.262, p = 0.058$ ). The results nearly show a mean difference that deviates from what we would expect to see by chance. This means that, while



the results do not meet the conventional threshold for statistical significance ( $p < 0.5$ ), they suggest that there is evidence that the engravings become more discriminable over time, given explicit pressures for group identification. Given that there was no difference in the

mean success rate between Generation 1 and Generation 2, testing the significance of this difference was unnecessary.

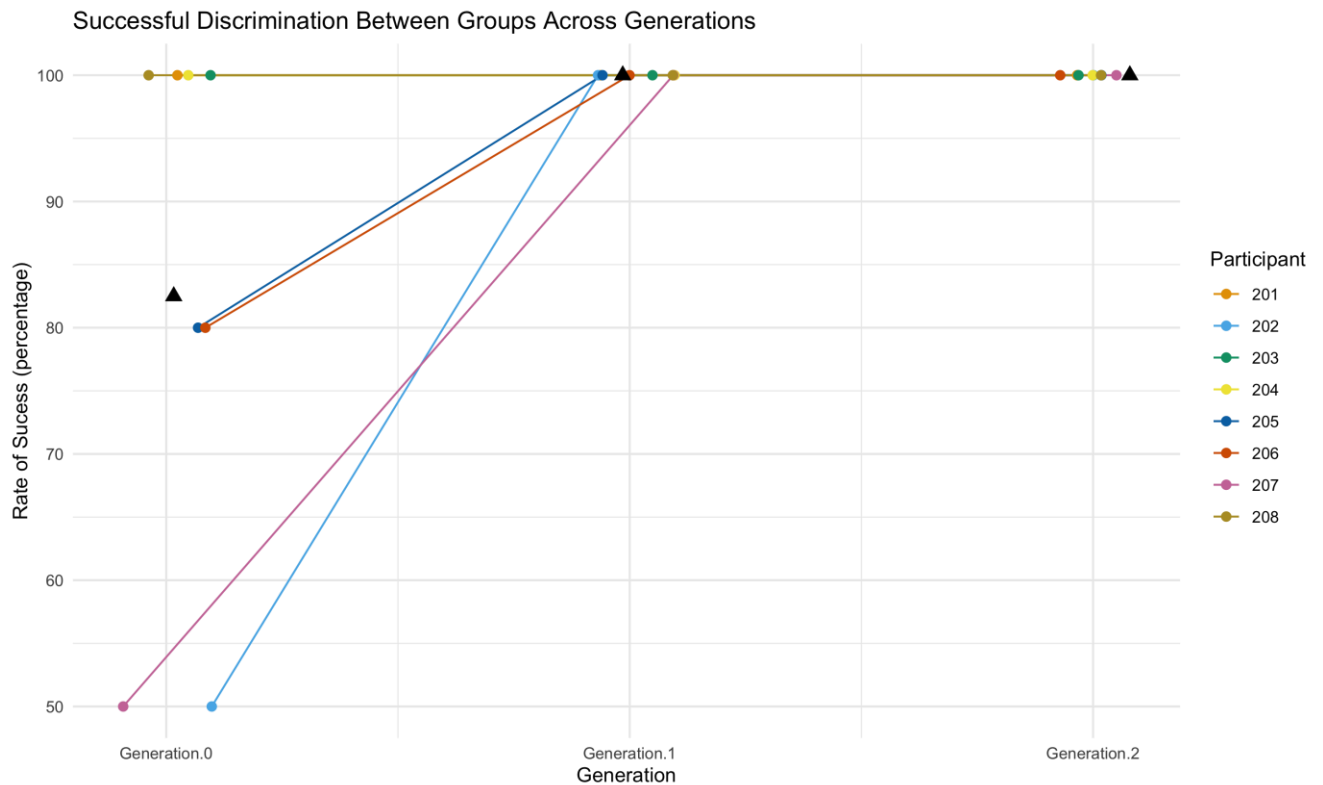


Figure 6: Plot of each participant's performance across generations in the Discrimination task. Mean performance across participants for each generation is marked with a black triangle.

Qualitative observations support the marginally significant results, strengthening the notion that participants had a significantly easier time sorting the engravings from later generations than those from Generation 0. Regardless of success rate, all participants took longer to sort these initial engravings than later engravings. These times were not explicitly measured (see Section 5.3) but were roughly halved or more between Generations 0 and 1. In post-task interviews, participants noted that the delineations between the two groups in Generation 0 were less clear compared to the obvious style present in the later generations. According to their testimonies during and after the task, participants were more certain of

their groupings of later generations than of the first, citing again the presence or absence of clear stylistic features.

### **Complexity of illustrations**

An interesting consequence of the Iteration task was that illustrations became increasingly complex in Cave A while remaining relatively simple in Cave B. Figure 5 clearly demonstrates the observed development of clear, complex stylistic features within Cave A, notably curved lines, increased numbers of lines, and varied line lengths.

Perimetric complexity measures were used to investigate illustration complexity quantitatively. Perimetric complexity is scale-invariant; given that the same pen was used for each illustration, the size of the drawing will not affect the complexity measure, given that line thickness remains generally consistent (Tamariz and Kirby, 2015). Using the algorithm in Pelli et al. (2006), where perimetric complexity is equal to the squared length of the inside plus the outside perimeters of the illustration divided by the ink area within those perimeters, individual complexity measures of each of the 24 illustrations were derived.

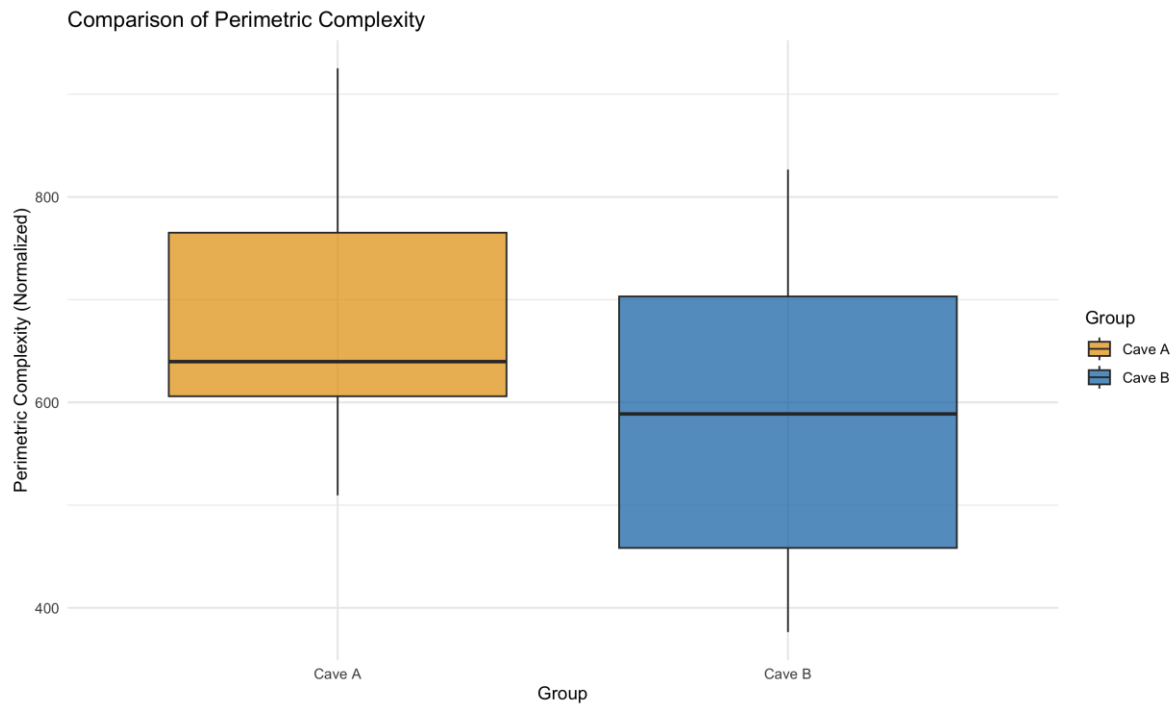


Figure 7: Comparison of distribution of perimetric complexity between Cave A (yellow) and Cave B (blue).

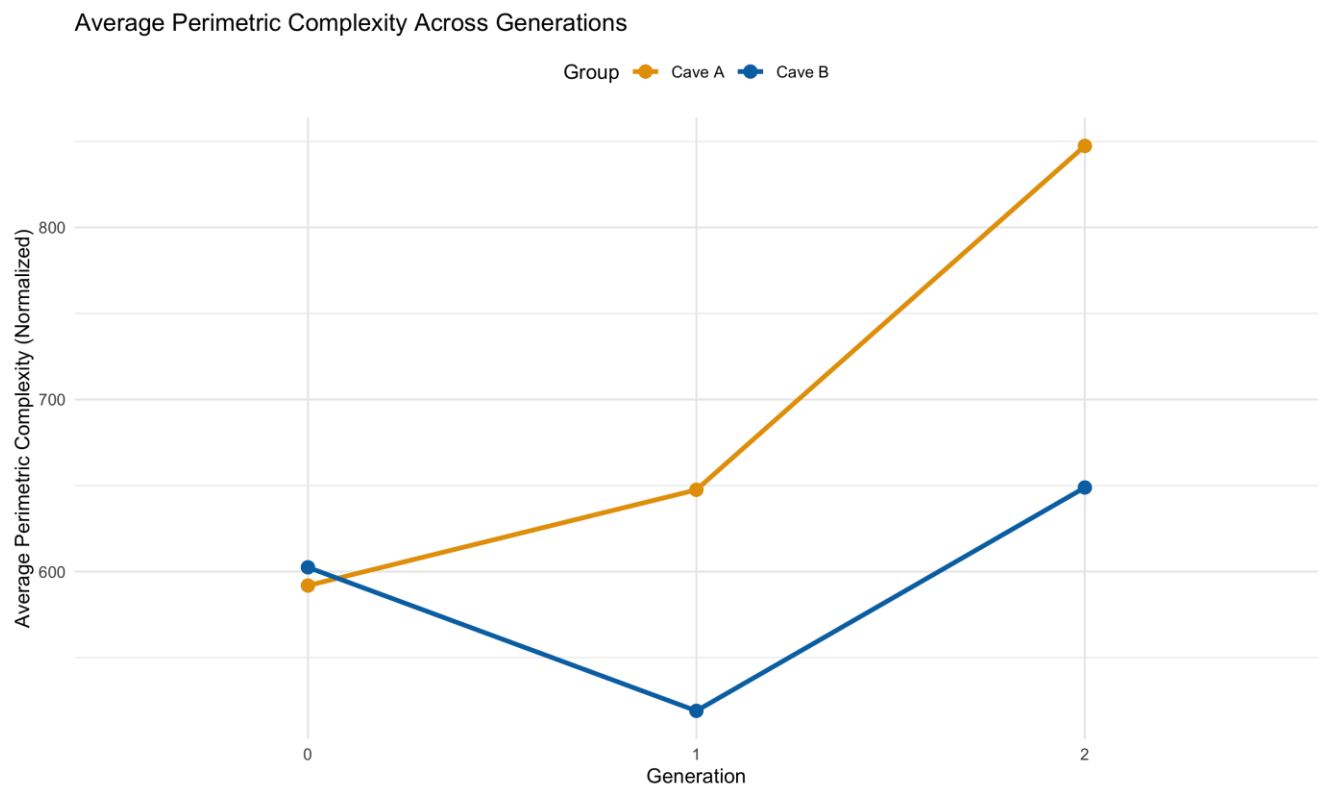


Figure 8: Plot of the average perimetric complexity across generations. Cave A is pictured in yellow; Cave B is pictured in blue.

Cave A has a higher mean perimetric complexity (695.588) than Cave B (590.121) across all generations, though a paired t-test showed that the difference in the mean perimetric complexity between Cave A and Cave B was not statistically significant ( $t(21.591) = 1.845, p = 0.079$ ) (Figure 7). This means that we fail to reject the hypothesis that the difference in mean perimetric complexity between Caves A and B is zero; in other words, the results do not show a mean difference that deviates from what we would expect to see by chance, and there is no quantitative evidence that the engravings from Cave A were notably more complex than those from Cave B.

Figure 8 demonstrates the trends of complexity for each group, with the initial generation to the left of each line and the final generation to the right. Cave A had a 36.679% increase in complexity throughout the Iteration task, whereas Cave B had a 12.048% increase. Both groups' symbols evolved to be more complex over time, and Cave A demonstrated both higher complexity in general and a higher rate of complexity change.

## **Discussion**

### **Style and Active vs. Passive Transmission**

While evidence from Tylén, et al. (2020) supports that the Blombos and Diepkloof engravings were part of cultural transmission within a social group, the question remains as to whether the stylistic development found over that 30,000-year period was active or passive. This question lies at the heart of the present study. Using an iterated learning experiment allows for control over this unknown variable, providing insight into expected patterns that could be observed in the archaeological record were the stylistic development to have been active. By introducing explicit pressures for group identification, my study corroborates Tylén, et al.'s (2020) findings that the engravings found at the Blombos Cave

and the Diepkloof Rock Shelter did not serve an active function as markers of group identity. The present study indicates that illustrations became easier to discriminate between groups, contrary to Tylén, et al.'s findings. Clear stylistic features developed over generations, and the illustrations became more complex, allowing novel participants to easily identify if an individual illustration belonged to one group or the other.

Tylén, et al. (2020) support the idea that Middle Stone Age *Homo sapiens* were becoming increasingly skilled at producing engravings, which resonated with the human cognitive system in salient ways. The increase in the average success rate among novel participants in my study indicates that there is some aspect of the illustrations between the two caves which makes them distinct in a systematic way. Style is the most obvious way in which this salience is recognized; Tylén, et al. point to increased complexity, structure, and symmetric line crossings in the Blombos and Diepkloof data. The divergence of style between the two groups was paramount to increased differentiability. Participants noted in post-experiment interviews that style was their primary consideration in their decision to place an illustration in one group or the other during the Discrimination task. Commonly cited stylistic features were line orientation, line shape (straight or curved), line numerosity, or general complexity.

Style also played a key role in the Iteration task. During the Iteration task, participants noted that they adopted the stylistic markers they observed as a means of situating their illustration within their designated cave; none of them indicated that they used certain stylistic elements, seen or unseen, simply due to aesthetic preference. This likely led to certain stylistic features becoming more prevalent or excluded in one cave or the other over generations. Style was not only a means of discriminating the engravings between groups but was an active consideration during the creation of the engravings as participants sought to identify with their designated social group.

This result—or one similar—was expected, given that an explicit pressure for group identification was added during the Iteration phase. Were Tylén, et al.’s results to be similar, then there would be evidence that the engravings found at Blombos and Diepkloof were created and transmitted with similar intent. However, Tylén, et al. did not find this to be the case. Given these considerations, the results of my study concur that there is little evidence that the Blombos and Diepkloof engravings served as active markers of group identity. This is not to say that the systematic stylistic development which occurred in each group happened purely by chance; it likely occurred passively as social groups transmitted engraving practices over this 30ky period.

### ***Complexity***

As noted in the Results section, a surprising result of the Iteration task is the emergence of a distinct difference in complexity between Cave A and Cave B. This distinction arose independently of any incentive given in the directions, suggesting that it developed as a consequence of the participants’ desire to differentiate one group from another. I will consider previous studies using graphical iterated learning experiments to investigate possible explanations for this distinction.

Tamariz and Kirby (2015) found that, without pressure for learning (the Copy condition), there is no consistent directionality in changes to complexity. Given that participants were not pressured to learn any features of the stimuli before creating their illustrations, we would expect to see similar results. Instead, there is a clear and rapid divergence of stylistic features, indicating that the social pressure had an interesting effect on the complexity across cave groups and generations.

Interestingly, some of the participants in Cave A purposefully made their drawings *more* complex, particularly in Generation 2 (Figure 5). After initially submitting their illustration to me, some of the Cave A participants took back their illustrations to add more

elements. The more the participant maximized for complexity—within the bounds of conventional features observed in Cave A—the more likely they thought it would be that a novel observer would place their illustration correctly in Cave A. A similar dynamic applied to Cave B; the simplicity of those engravings became a stylistic feature in itself. In the final generation, there is a trend for the symbols from Cave B to converge on elements of line number and size; three of four have five vertical, parallel lines, increasing in length (Figure 5). Though the task was not explicitly timed, participants tended to take longer to plan and execute their illustrations to fit in with Cave A than with Cave B.

Based on participant testimony, these stylistic differences were, in fact, the key to both easy reproduction of and successful attribution of illustrations to their Cave groups for the later generations. This probably would have either plateaued or lessened given more generations of study, as time considerations would hinder the participants from adding much more additional complexity to their illustrations.

Caldwell and Smith (2012) found that referential signs become less complex across generations when there is pressure for social grounding. This contrasts with Tamariz and Kirby' (2015) observations about non-referential signs maintaining their complexity in grounded contexts (where the participant is continuously interacting with the target). These experiments focus on clearly referential or non-referential communication; social meaning is less specific and perhaps sits in between this dichotomy. This might explain the divergence of complexity and simplicity across generations, but further exploration is needed to explain the role of social communication and graphical complexity.

### **Limitations and areas for further study**

This study provides further exploration of Tylén et al.'s (2020) cultural connotation hypothesis and informative insight into the role early engravings may have played in the

development of symbolic cultural transmission processes. However, there are ways this study could be improved or extended, given further time and resources.

The small sample size leads to obvious limitations concerning the scope of the study. Having more generations participate in the Iteration task may reveal patterns that take longer to materialize, such as convergence of symbols or ceilings on complexity. Perhaps the drawings would become more similar to each other; likely, they would become more convergent but less complex, especially for the illustrations in Cave B. Further information about the discriminability of the cave groups would be revealed if more participants took part in the Discrimination task; there is a measurable trend suggesting that discriminability between groups improves over generations, but more data would improve the statistical significance of this measure and further back it as support for the hypothesis at hand.

Any instructions or incentives given to the participants of this study were inherently linguistic, which, by most accounts, would not have been the case in the Middle Stone Age when the Blombos and Diepkloof engravings were being created and diffused. Certain elements of human cognition mean we can extend current experimental practices to inform how early humans would have responded to a number of tasks, including the diffusion chain paradigm implemented in this study, but the element of linguistic instructions and explanations might bias participants and their behaviour in some way. This may be unavoidable or not impact the findings of the study, but it is important to note, and it would be worthwhile to explore a paradigm that is entirely non-linguistic. Computational approaches using artificial agents have proved successful in removing the linguistic element from other iterated learning experiments, so that avenue of enquiry may be promising (e.g. Kirby et al., 2008; Smith et al., 2003).

Garrod, et al.'s (2010) findings suggest that an interactive model leads to improved identification accuracy, as opposed to a diffusion chain model. Fay et al. (2018) concur with this finding, showing in their study that observation-then-reproduction was sufficient for cumulative cultural evolution, but the precision of transmission was improved through collaborative learning. Though the paradigm used in this study attempted to incorporate elements of social grounding, the lack of face-to-face interaction or joint creation or use means that the development of these symbols was effectively constrained to the effects observed through vertical transmission.

One benefit of this particular iterated learning task was the introduction of a horizontal learning element, namely that a group of drawings introduced to the data set at different times was shown to each participant, with participants around the same chronological stage of the development constituting a 'generation'. A notable contrast between the present study and other iterated learning studies is that the audience was unknown to the participants of the present study; they were asked by the researcher to make their drawing distinguishable by a novel viewer of the engravings. Other studies which explicitly test horizontal transmission do so by introducing an element of social grounding. The pressure to telegraph information to an unknown audience extenuated the social pressure but undermined the use of the symbols as a means of intergroup communication.

Upon reflection, the categorization of 'generations' was more useful as an analytical tool than as an element of interactivity. It would be informative to see a version of this study which involved Interaction and Chain conditions, similar to those used in Garrod, et al. (2010), and see if different results or patterns emerge.

## Conclusions

This study provides new empirical insight into the social role of symbolic communication in the Middle Stone Age. By applying a graphical communication paradigm to the existing archaeological record from the Blombos Cave and the Diepkloof Rock shelter, it offers evidence that stylistic features evolve to facilitate group differentiation when explicit pressures for identity marking are present. However, the results also support Tylén et al.'s (2020) conclusion that the Blombos and Diepkloof engravings likely developed as a passive consequence of cultural symbolic transmission rather than as active markers of group identity.

By comparing the results of these studies, it can be inferred that the Blombos and Diepkloof engravings were not under pressure to be learned and were developed through interactive co-creation of symbols within social groups. It was unlikely that Middle Stone Age humans were actively engaging in group differentiation through symbolic communication based on the discrepancies between the results of Tylén et al.'s (2020) forced-choice discrimination tasks and my group-matching discrimination task. Were the engravings to have served as active markers of group identity, then we would expect to see increased rates of successful discrimination in both tasks. However, we do not, indicating that, while the clear development of style over a period of 30ky suggests that cognitive pressures were converging on socially salient patterns, they were doing so passively.

The emergent mechanism of symbolic style adoption and transmission supported by this study closely maps onto sociolinguistic principles. Among contemporary humans, language is the primary way in which we communicate, construct social identities, and maintain community relationships (Young, 2008). Language is a social object which derives meaning from its use in speech communities—communities which share social conventions and environments. The convergence of linguistic style is common as individuals make

themselves sound more like those in their speech communities (Van Herk, 2012). The social communities we see emerging at the Blombos and Diepkloof caves demonstrate elements of this social stylistic convergence, no matter how passive; were we to find evidence of swift divergence between groups like I do in my study, I would say this is strong evidence of the sorts of social differentiations we see among speech communities in the modern day.

This dissertation has shown that empirical study and archaeological research can work in conjunction to build a more informative model of early human behaviour, especially from a linguistic standpoint. Iterated learning experiments and graphical communication paradigms should be utilized in this pursuit, as they can help inform evolutionary processes and provide insight into the relationship between symbolic communication and cumulative cultural evolution.

## References

- Bickerton, D. (2007). Language evolution: A brief guide for linguists. *Lingua*, *117*(3), 510–526. <https://doi.org/10.1016/j.lingua.2005.02.006>
- Brighton, H., Smith, K., & Kirby, S. (2005). Language as an evolutionary system. *Physics of Life Reviews*, *2*(3), 177–226. <https://doi.org/10.1016/j.plrev.2005.06.001>
- Caldwell, C. A., & Smith, K. (2012). Cultural Evolution and Perpetuation of Arbitrary Communicative Conventions in Experimental Microsocieties. *PLOS ONE*, *7*(8), e43807. <https://doi.org/10.1371/journal.pone.0043807>
- Fay, N., Ellison, T. M., Tylén, K., Fusaroli, R., Walker, B., & Garrod, S. (2018). Applying the cultural ratchet to a social artifact: The cumulative cultural evolution of a language game. *Evolution and Human Behavior*, *39*(3), 300–309. <https://doi.org/10.1016/j.evolhumbehav.2018.02.002>
- Godfrey-Smith, P. (2014). Signs and Symbolic Behavior. *Biological Theory*, *9*(1), 78–88. <https://doi.org/10.1007/s13752-013-0140-0>
- Henshilwood, C. S., d’Errico, F., van Niekerk, K. L., Coquinot, Y., Jacobs, Z., Lauritzen, S.-E., Menu, M., & García-Moreno, R. (2011). A 100,000-Year-Old Ochre-Processing Workshop at Blombos Cave, South Africa. *Science*, *334*(6053), 219–222. <https://doi.org/10.1126/science.1211535>
- 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*(1), 27–47. <https://doi.org/10.1016/j.jhevol.2009.01.005>
- Henshilwood, C. S., & Marean, C. W. (2003). The Origin of Modern Human Behavior: Critique of the Models and Their Test Implications. *Current Anthropology*, *44*(5), 627–651. <https://doi.org/10.1086/377665>

Henshilwood, C. S., Watts, I., & Tribolo, C. (2002). Emergence of modern human behavior: Middle Stone Age engravings from South Africa. *Science*.

[https://www.academia.edu/1560495/Emergence\\_of\\_modern\\_human\\_behavior\\_Middle\\_Stone\\_Age\\_engravings\\_from\\_South\\_Africa](https://www.academia.edu/1560495/Emergence_of_modern_human_behavior_Middle_Stone_Age_engravings_from_South_Africa)

Kirby, S., Cornish, H., & Smith, K. (2008). Cumulative cultural evolution in the laboratory: An experimental approach to the origins of structure in human language. *Proceedings of the National Academy of Sciences*, *105*(31), 10681–10686.

<https://doi.org/10.1073/pnas.0707835105>

Morgan, T. J. H., Uomini, N. T., Rendell, L. E., Chouinard-Thuly, L., Street, S. E., Lewis, H. M., Cross, C. P., Evans, C., Kearney, R., de la Torre, I., Whiten, A., & Laland, K. N. (2015). Experimental evidence for the co-evolution of hominin tool-making teaching and language. *Nature Communications*, *6*(1), 6029.

<https://doi.org/10.1038/ncomms7029>

Parkington, J. (2005). From tool to symbol: The behavioural context of intentionally marked ostrich eggshell from Diepkloof, Western Cape. *From Tools to Symbols: From ....*

[https://www.academia.edu/19735022/From\\_tool\\_to\\_symbol\\_the\\_behavioural\\_context\\_of\\_intentionally\\_marked\\_ostrich\\_eggshell\\_from\\_Diepkloof\\_Western\\_Cape](https://www.academia.edu/19735022/From_tool_to_symbol_the_behavioural_context_of_intentionally_marked_ostrich_eggshell_from_Diepkloof_Western_Cape)

Peirce, C. S. (1998). *Charles S. Peirce: The Essential Writings*. Prometheus Books.

Pelli, D. G., Burns, C. W., Farell, B., & Moore-Page, D. C. (2006). Feature detection and letter identification. *Vision Research*, *46*(28), 4646–4674.

<https://doi.org/10.1016/j.visres.2006.04.023>

Smith, K. (2022). How Language Learning and Language Use Create Linguistic Structure. *Current Directions in Psychological Science*, *31*(2), 177–186.

- Smith, K., Kirby, S., & Brighton, H. (2003). Iterated Learning: A Framework for the Emergence of Language. *Artificial Life*, 9(4), 371–386.  
<https://doi.org/10.1162/106454603322694825>
- Sterelny, K., & Hiscock, P. (2014). Symbols, Signals, and the Archaeological Record. *Biological Theory*, 9(1), 1–3. <https://doi.org/10.1007/s13752-013-0154-7>
- Tattersall, I. (2017). How can we detect when language emerged? *Psychonomic Bulletin & Review*, 24(1), 64–67. <https://doi.org/10.3758/s13423-016-1075-9>
- Texier, P.-J., Porraz, G., Parkington, J., Rigaud, J.-P., Poggenpoel, C., Miller, C., Tribolo, C., Cartwright, C., Coudenneau, A., Klein, R., Steele, T., & Verna, C. (2010). From the Cover: A 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 Sciences of the United States of America*, 107(14), 6180–6185.  
<https://doi.org/10.1073/pnas.0913047107>
- Texier, P.-J., Porraz, G., Parkington, J., Rigaud, J.-P., Poggenpoel, C., & Tribolo, C. (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(9), 3412–3431. <https://doi.org/10.1016/j.jas.2013.02.021>
- Tobias, P. V. (2005). *From Tools to Symbols: From Early Hominids to Modern Humans* (F. d’Errico & L. Backwell, Eds.). Wits University Press.  
<https://doi.org/10.18772/22005064174>
- Tylén, K., Fusaroli, R., Rojo, S., Heimann, K., Fay, N., Johannsen, N. N., Riede, F., & Lombard, M. (2020). The evolution of early symbolic behavior in Homo sapiens. *Proceedings of the National Academy of Sciences*, 117(9), 4578–4584.  
<https://doi.org/10.1073/pnas.1910880117>
- Van Herk, G. (2012). *What is Sociolinguistics?* Wiley-Blackwell.

Wisher, I., & Tylén, K. (2024). *Experimenting with the past: An integrative approach to early symbolic evolution*. OSF. <https://doi.org/10.31234/osf.io/u2jgz>

Young, R. (2008). *Language and interaction: An advanced resource book* (First published).  
Routledge.