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# What processes sparked off symbolic representations?

## A reply to Hodgson and an alternative perspective

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### Abstract

The neurovisual resonance theory (NRT) proposes a framework for interpreting the earliest abstract engravings. It postulates that the first engraved marks produced by hominins reflected predilections of the early visual cortex for simple geometric patterns and served aesthetic rather than symbolic purposes. In a recent article published in this journal the proponent of this theory provides a synthesis of neuroimaging studies that he perceives as supporting his theory while criticising a recent neuroimaging study, conducted by some of us, that explores the possible symbolic function of the earliest engraved marks. In this paper, we point to a broader range of literature backing up our interpretation, scrutinize theoretical claims put forward by Hodgson, and test them against empirical evidence. We conclude that these data are supportive of the hypothesis that the earliest engravings served a representational purpose and may have played a symbolic function.

### Keywords

Symbolism, Engraving, Cognitive Archaeology, Neurovisual Resonance Theory, fMRI, Palaeolithic

### Introduction

Hodgson’s Neurovisual Resonance Theory (NRT) proposes a mechanism to explain the origin and understand the significance of the earliest engravings produced by members of our genus (Hodgson,

2006, 2014). According to the NRT, the propensity of hominins to produce abstract engravings is closely tied to the way the primary visual cortex processes incoming information and, in particular, to its sensitivity to geometric primitive of percepts such as orientation and ends of lines or edges. He considers that his view finds support in experimental results published by Changizi et al., (2006) according to which these primitives are the most frequently patterns encountered in the visual environment and whose discrimination may have had provided selective advantages to our ancestors. Such a propensity would have created an increased sensitivity for these patterns that would have pushed our ancestors to reproduce them via engraving on a variety of media. Hodgson speculates that since our ancestors had an aesthetic interest in perceiving geometric primitives, their material representation would have played a “proto-aesthetic” rather than representational function (Hodgson 2006). While relying to some extent on published neuroscientific data, NRT has not been the subject of empirical research. In his last article, Hodgson explores the implications of a neuroimaging study conducted by some of us for the NRT (Mellet et al., 2019). In his attempt to comment on our results, however, he draws conclusions from them that are, in our view, in contradiction with the empirical data. In this study, functional Magnetic Resonance Imaging (fMRI) was used to compare brain activations triggered by the perception of tracings of the earliest known engravings dating between 540 ka and 30 ka to those elicited by the perception of outdoor scenes, objects, symbol-like characters and written words. A major result of this study was that the perception of abstract patterns engaged regions along the occipito-temporal cortex in a similar way than the perception of objects. A second result was that activation in primary visual area resulting from the perception of the Palaeolithic engravings did not differ from the perception of their “scrambled” disorganized versions, suggesting that these areas were not specifically engaged in the processing of the engravings. These results appeared to us in contradiction to the central role attributed by NRT to the primary visual area in the processing of these stimuli. Taken as a whole, we interpreted our results as supporting the view that the earliest engravings may have had a representational purpose and may have been used symbolically. Hodgson’s (2019) reading of our results offers the opportunity to further clarify the significance of the results reported in Mellet et al. (2019). The main objective of this reply is to set the record straight and build on our results, novel archaeological data and recent advances in cognitive science to discuss the hypotheses proposed by Hodgson and test them against the available data so as to shed light on the significance of the first known representations.

### **Theoretical pitfalls of the NRT**

One of the key claims of NRT (Hodgson 2006) is that the production of early geometric patterns by hominins depends on how their “visual brain” extracted geometric primitives from the world and used the latter to construct forms. Under this view, the production of early geometric engravings would have derived from the influence of the visual system, attuned to perceive those geometric primitives, on the motor system engaged in producing marks. This theory has several weaknesses, which are only marginally highlighted in the literature (Froese et al., 2014; Verpooten and Nelissen 2012).

First, Hodgson ascribes considerable relevance to the claim that similarities in writing systems are due to our inclination to privilege the perception of junctions and intersections, and to the hypothesis, put forward by Changizi et al. (2006), that this ability evolved due to the salience of such patterns in natural scenes. According to Hodgson, the earliest engravings stem from the same process. However, the preliminary nature of the results presented by Changizi and colleagues, with regard to the relationship between signs considered as “geometrical primitive” (L, T, X) and natural scenes, is to be noted. The identification of main orientations and junctions present in natural scenes was done in

Changizi et al. study by observers using their subjective judgment, not by automated image analysis. The observers were undergraduate students who, trained by the senior author, co-authored the study, and the study does not specify whether the observers were aware of the working hypothesis the study was seeking to test when they were submitted to the task. In addition, the inclusion in the Changizi sample of a large number of culturalized landscapes (with modern buildings and other human made constructions) may be at the origin of an overrepresentation of geometric primitives. Salient features are heavily dependent on geography and ecology, and vary from place to place. Deserts are characterized by virtually no straight vertical lines whereas in bamboo forests they are abundant and other landscapes abound in irregular patterns of all kind, including curved lines. Without wishing to diminish the value of the pioneering study by Changizi et al., we feel that it is premature to accept that the features they identify as geometric primitives are indeed the most frequent or salient in natural scenes. Consequently, the hypotheses drawn from Changizi et al.'s results cannot be considered as established laws in the way Hodgson seems to claim.

Second, Hodgson's attempt to support his theory with the "Local Combination Detector" model proposed by Dehaene et al. (2005) draws on a misleading causal chain between the phenomena to which he refers. This model proposed that hierarchical local neuronal networks in primary visual cortex and close surrounding areas are tuned to detect local shape, from oriented bars to letters. There is no doubt that the "lower visual cortex, i.e. V1 and V2 is biased towards certain line configurations that make it apposite for recognising written words" (Hodgson 2019, p. 589). However, the key point as far as reading is concerned, is not just the visual shape of written marks but the link of those marks with phonology and semantics (lexical meaning). This explains, indeed, why baboons may be trained to distinguish words from non-words "while remaining oblivious of the semantic content" (Hodgson 2019, p. 589). In other words, it is clear that previous evolutionary processes constrained subsequent developments, but this does not imply that the latter are *sufficient* to explain the former.

Third, available data on brain evolution indicate that the human primary visual cortex is only ~60% the size it should be for a primate brain that size and basically shows the same anatomy observed in our close relatives (Holloway 1992; Schoenemann 2006) while other areas, such as the temporal lobes, have substantially increased their volume and diversified their morphology and functions. This observation does not support the hypothesis, implicit in NRT, that the primary visual cortex was exapted for new functions, i.e. increased recognition and processing of abstract patterns, and rather support the opposite view, that more integrated visual areas played a growing role in the recognition of visual stimuli.

Fourth, Hodgson argues that since the primary visual cortex privileges the recognition of line junctions over other natural visual stimuli, one should expect that the earliest graphic representations "mirror (resonate) the elemental topological features that the early visual cortex is primed to process" (Hodgson, 2019 p. 589). However, this explanation is not only remarkably silent, as discussed above, on what kind of mechanism would have produced this "resonance" but also on why such a resonance should have led to the material reproduction of these features. Our close relatives are apparently equally sensitive to repetitive lines, angles, and grids, but do not feel any urge to embed them in their material culture. *If*, at the beginning of the process, the motivation behind observing these patterns was uniquely aesthetic or even just, as Hodgson proposes, "proto-aesthetic", and *if* these patterns represented – which is debatable – recurrent features in the environment, what would have been the need to reproduce them artificially instead of just being enchanted by recurrently perceiving them in the natural surroundings? To explain how this may have come about, Hodgson suggests that hominins "distilled" these natural features and "enunciated" them in a "tangible purified format". The ambiguity

implicit in this terminology hides the issue of how geometric primitives salient at the subconscious level (for spatial perception) could be recruited at the conscious level for producing abstract patterns.

Fourth, the terminology used by Hodgson makes one wonder what kind of evolutionary mechanism Hodgson thinks may have determined such a “distillation”. In other words, what kind of selective advantages would this intermediate, pre-semantic, stage of representation production has for hominins’ cognition apart from an aesthetic reward? Has this happened at a purely individual level, at the scale of a community, of a culture, or a (fossil) species? In the first case, one would expect different individuals to independently rediscover, at different times during this intermediate stage, the proto-aesthetic value of joining and crossing lines and to reproduce different patterns with different techniques and on a variety of media. The continuity in media (ochre, ostrich egg shell, bone), technique (engraving, drawing) and, to some extent, represented patterns that characterises some of the early instances of image making discussed by Hodgson (e.g., those from Blombos and Diepkloof) contradicts the idea of representations conceived to elicit a sort of self-centered proto-aesthetic perception. At Blombos, for example, bones and marine shells are well preserved and could have been systematically engraved with abstract patterns, which is not the case. At Diepkloof abstract engravings could have been produced on bone and ochre fragments and were instead only made on ostrich eggs. It is essential to this debate that some of the engraved patterns found at Blombos are very small in size and barely visible to the naked eye. This appears to better fit a symbolic function restricted to a small community, such as that of marks of individual- or group-ownership (Henshilwood and d’Errico, 2011) than a proto-aesthetic perception. No apparent logic reason exists for producing small engravings on media that would have easily fitted large and more visible ones if the intent was that of “enunciating” natural patterns in “a tangible purified format”.

When a pattern-making behaviour is shared by the members of a community, how long should we expect “a proto-aesthetic perception” to remain the unique function of these patterns before a semantic dimension takes over? One may reasonably argue: a very short while indeed, if any. There is a remarkable difference between the *perception* of geometric patterns and their *deliberate production*, which requires not only a *motivation* but also a social context, a technology, a knowledge of the media on which the pattern is going to be incised, and the motor skills to apply such technology successfully and to reach the desired goal. The maintenance of this practice entails dedicated modes of cultural transmission that allow members of the new generations to acquire the know-how necessary to perpetuate the practice. It also entails, since no utilitarian reasons appear to be attached to the earliest engravings, to understand their significance for the group and thus – we would argue – their *meaning*.

### **From marking to meaning**

The above inconsistencies beg the question of whether we really need to theorize an intermediate proto-aesthetic stage to account for the emergence of semantic representations, or whether more parsimonious and realistic scenarios can explain this phenomenon. The main incongruity of NRT, the lack of logical explanation as to why proto-aesthetic enjoyment of recurrent natural features should trigger agency, disappears if one assumes that both agency and an adapted cognitive setting were already in place when the former was put at the service of the latter. Hominins have been marking bone with stone tools during butchery activities for at least 2.6 Myr. Cut marks resulting from these activities often take the form of sets of juxtaposed or intersecting incisions (Figure 1). This utilitarian activity may have been crucial for the development of the motor and cognitive skills necessary to

produce durable, visible markings and to enhance their perception. Once the ability to produce such marks was in place, the next steps would have been to attribute some sort of meaning to them.

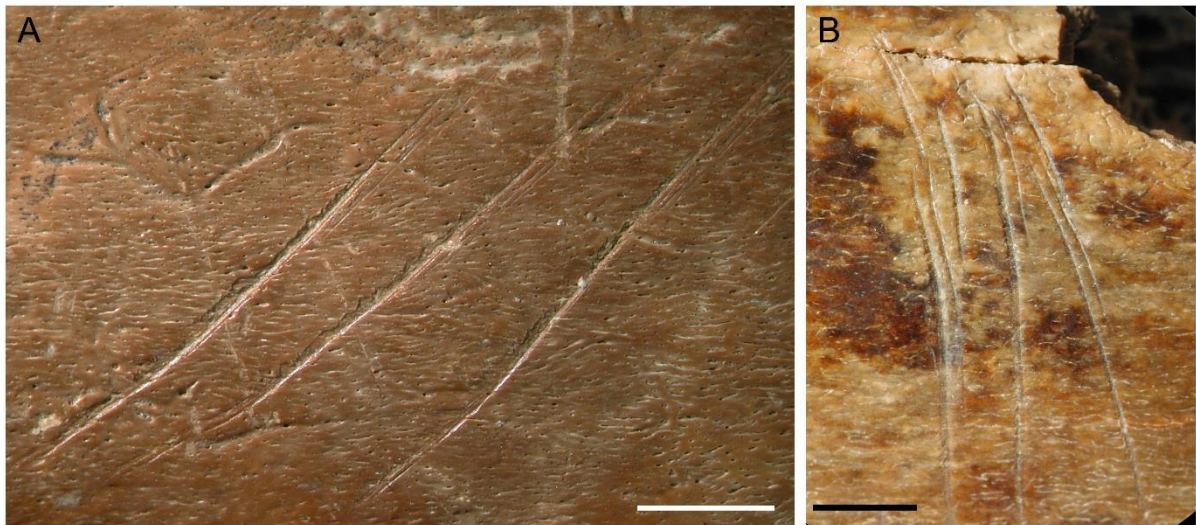


Figure 1. Sets of subparallel cut marks on bone remains from Linjing, China (photos F. d’Errico). Scale = 1cm

In his 2006 paper, Hodgson asks “why do graphic primitives [i.e. simple geometric patterns] appear to predate 2D representational images by such a long period [at least by about 50,000 years]? Logically, one would expect representational depictions to predate geometric motifs as the former would, to archaic humans, have had more of an obvious relevance and appeal than the latter. And objects are readily available in the environment that can be copied, whereas geometric shapes appear to be a rare to almost non-existent commodity.” However, the fact that, contrary to this claim, simple geometric patterns were available to archaic hominins as by-products of butchery activities suggests that the visual appearance of those marks (and therefore the role of the early visual cortex) may be less relevant than the mechanisms by which the motor abilities to produce such marks were exploited – we would say “exapted” (d’Errico and Colagè 2018; Colagè and d’Errico 2018; D’Ambrosio and Colagè 2017) – for more symbolic and less utilitarian aims. This makes the attribution of meaning to engravings the real issue at stake here. The exaptation of markings made on bone for utilitarian purposes can explain the repeated and independent creation of semantic markings without the need to resort to a “neurovisual resonance” or a “proto-aesthetic” stage. The emphasis, in *our* scenario, would be on the demographic, social, and ecological contexts favouring the innovation and the receptiveness of a culture to create, maintain, and transmit this innovation (Tennie et al., 2009; Heyes, 2018).

While it is correct that writing systems emerged around 5500 BP, presumably as a concomitant of state-like polities and their infrastructural demands, this does not imply that external representations were a late invention. As Morin et al. (2018) convincingly argue, graphic codes may serve various purposes only one of which (i.e., asynchronous communication) presupposes full-fledged literacy and is rather demanding in terms of social cognition and pragmatic skills. Graphic codes for other purposes (such as emblems or memory aides) would have emerged much earlier from non-standardized graphic elements, with signs indicating ownership and numerical notations being the most likely candidates for external representations even in ancient times (d’Errico et al., 2018; Overmann, 2016). This implies that even if “considerable effort and commitment are required before the Visual Word Form Area

asserts itself” (Hodgson, 2019, p. 591), as required for a full-fledged literacy, the step-wise evolution from producing simple graphic elements through graphic codes to writing would still be possible through cultural exaptation.

Hodgson is apparently critical of d’Errico and Colagè (2018) approach to the emergence of cultural innovations. However, these authors focus on much more recent processes than those addressed by Hodgson’s (2006) Neurovisual Resonance Theory, which concerns the evolutionary forces shaping the early visual cortex all along the natural history of the primates and the way “the brain construct forms” (Hodgson 2006, p. 56). While d’Errico and Colagè (2018) do not deny the constraints that previous evolution may have imposed on the ventral visual stream (p. 224 and their Fig. 2), they focus on the process of cultural exaptation by which incised objects may have been “exploited for inaugural symbolic purposes” (Hodgson, 2019, p. 591-2), and on the ensuing process of “cultural neural reuse” by which more anterior sectors of the ventral visual stream may have been recycled in artificial memory systems and, eventually, for reading. As for the latter point, the issue is not the basic characters of the geometric shapes used to represent and convey symbolic meaning (which obviously are constrained by the fundamental properties of the visual cortex), but the way in which the brain re-organizes in order to connect specific kinds of visual shapes with either phonology or semantics (i.e., essentially, a lexicon). There is no doubt that “learning is constrained by evolutionary instantiated pre-existing (or prewired) neural circuits”. However, the neuronal recycling of the middle portion of the fusiform gyrus that becomes, in literates, the Visual Word Form Area (VWFA) does not just concern visual processes. There are studies showing that – in contrast to illiterate subjects or in contrast to the right-hemisphere homologue of the VWFA in literates – the recycling of the VWFA involves the functional (Caspers et al., 2014, Stevens et al., 2017) and structural (Thiebaut de Schotten et al., 2014; Yeatman et al., 2012; Carreiras et al., 2009) connectivity of this portion of the left ventral visual stream with other and distant brain regions involved, most of which relates to the processing of the phonological or the lexical-semantic aspects of language. Accordingly, Mellet et al. (2019) reported that VWFA was co-activated with left temporal and frontal regions when participants were presented to words. Therefore, the real issue at stake is the creation of a link between the visual appearance of the marks, the motor ability of producing such marks (see below), and the phonological and/or semantic meaning the marks may convey (Dehaene and Cohen, 2011; Dehaene et al., 2015; d’Errico and Colagè, 2018; Colagè and d’Errico, 2018). In other words, the study by Mellet et al. (2019), as well as that by d’Errico and Colagè (2018), concerns the attribution of some kind of cultural *meaning* to non-utilitarian marks, rather than the deep origin of the geometric and visual characteristics of the marks employed with that aim (which do have, of course, evolutionary bases).

On archaeological grounds, Hodgson claims that his theory is supported by the observation that, in the earliest instances of human-made engravings, “accidentally-made, as well as natural patterns are often incorporated into the intentional marks”. This is an assertion that can be verified empirically. Table 1 lists the Lower Palaeolithic, Middle Palaeolithic, and Middle Stone Age sites that have yielded engravings, as well as information on their geographical location, chronology, number of engravings found at each site, and type of engraved motif. This list includes all the engravings used in the study by Mellet and colleagues (2019) as well as others that the latter study could not include for various reasons, or that were published after its experimental protocol was established. For each site, we indicate whether certain engravings bear traces of accidental or natural marks (cracks, natural grooves, chemical alterations etc.) that may have inspired the engraver. We also pinpoint cases in which ochre fragments were *deliberately flattened* by grinding to produce a facet that was subsequently engraved (Figure 2). Half of our diagnosis is based on the direct analysis of the objects, conducted under optical

microscope by one of us (FD), and for the other half on good quality photos. The quality of the available photos does not allow a definitive conclusion in four cases. The analysis of this dataset clearly shows that natural or accidentally made patterns are either absent or extremely rare on objects bearing the earliest known engravings. This contradicts Hodgson's assertion that the engravers were inspired by patterns already present on the objects. This idea is also contradicted by the choice of media such as ostrich eggshells and fresh water shells, which do not present natural patterns that may resemble the engravings produced on their surface. Hodgson's assertion is further contradicted by the fact that, in some cases, the natural surface of the object was artificially removed, most likely to improve the perception of the patterns subsequently engraved on them (Figure 2).



**Table 1. Occurrence of accidentally-made marks and natural patterns on early engravings**

Site	Region	Material	No. of objects	Cultural Attribution*	Age (kyr BP)	Description*	Reference	Direct analysis	Photo	Photo of low quality	Accidentally-made marks	Natural patterns	Grinding before engraving
<b>Africa</b>													
Blombos	South Africa	Ochre; Bone	19	MSA	100-75	CH; PAR; CC	d'Errico et al. 2001; Henshilwood et al. 2002, 2009	19			0	1 ?	2
Border Cave	South Africa	Bone; Stone	4	MSA	60-44		d'Errico et al. 2012	3	1		0	0	0
Diepkloof	South Africa	OES	409	MSA	65-55	SPL; CL; CHB	Texier et al. 2010		7		0	0	0
Goda Buticha	Ethiopia	OES	10	LSA/MAS	6-43	CC	Assefa et al. 2018		10		?	0	0
Klasies River	South Africa	Ochre	1	MSA II	100-85	SPL	d'Errico et al. 2012	1			0	0	1
Klein Kliphuis	South Africa	Ochre	1	MSA	80-50	SPL; CH	Mackay and Welz 2008		1		0	0	0
Klipdrift Shelter	South Africa	OES	110	MSA	65-59	CH; CC; SPL	Henshilwood et al. 2014;		6		0	0	0
Pinnacle Point	South Africa	Ochre	1	MSA	100	SPL	Watts 2010		1		0	0	1
Palmenhorst	Namibia	Stone	1	MSA	Undated	CH; CC; PAR	Henshilwood and d'Errico 2011		1	1	0	1?	0
Sibudu Cave	South Africa	Ochre	29	MSA	77-58	PAR; FL	Hodgskiss 2014		12		0	0	?
Wonderwerk Cave	South Africa	Ochre	1	MSA	70	PAR	Bednarik and Beaumont 2012; Beaumont and Bednarik 2013		1		0	0	0
<b>Europe</b>													
Bacho Kiro	Bulgaria	Bone	1	MP-M	>47	ZZ	Marshack 1976, 1982		1	1	0	0	0
Bilzingsleben	Germany	Bone	2	LP	412-320	SPL; FL	Mania and Mania 1988		2		0	0	0
Ermitage	France	Bone	1	MP-M	>31	PAR; SPL	Pradel and Pradel 1954; d'Errico 1998		1	1	0	0	0
Gorham's Cave	Gibraltar	Bedrock	1	MP-M	>39	CH	Rodriguez-Vidal et al. 2014	1			0	0	0
Kiik-Koba	Crimea	Flint cortex	1	MP-PM	35-37	SPL	Stepanchuk 2006, Majkić et al. 2018	1			0	0	0
Kozarnika	Bulgaria	Bone	1	LP	900	PMK	Sirakov et al. 2010; Ivanova 2009; Guadelli and Guadelli 2004		1		0	0	0
Krapina	Croatia	Bone	1	MP	130	PMK	Frayer et al. 2006		1		0	0	0
La Ferrassie	France	Bone	1	MP-M	65	PMK	Capitan and Peyrony 1912; Zilhao 2007		1	1	0	0	0
Mamontovaya Kurya	Russia	Tusk	1	MP-M	36	SPL	Pavlov et al. 2001; Svendsen, Pavlov 2003		1		0	0	0
Pradelles	France	Bone	1	MP-M	60-70	PMK	d'Errico et al. 2018	1			0	0	0
Pešturina	Serbia	Bone	1	MP-Ch/Qt	95-64	SPL	Majkić et al. 2017	1			0	0	0
Temnata Dupka	Bulgaria	Stone slab	1	MP	50	PAR	Cremades et al. 1995; Tsanova 2006		1		0	0	0
Unikote	France	Bone	1	MP-M	>30	PMK	d'Errico et al. 2009	1					
Vaufray	France	Antler	1	MP	120	PMK	Vincent 1988	1			0	0	0
Zaskalnaya VI	Crimea	Bone	1	MP-M	40	PMK	Majkić et al. 2018	1			0	0	0
<b>Middle East</b>													
Qafzeh	Israel	Flint	1	MP-M	100	PAR	Hovers et al. 1997	1			0	0	0
Quneitra	Israel	Flint	1	MP-M	50	CO	Goren-Inbar 1990; Marshack 1996; d'Errico et al. 2003	1			0	0	0
<b>Asia</b>													
Linjing	China	Bone	2	MP	110	PAR	Li et al. in press	2			0	0	0
Shuidonggou	China	Stone	1	EUP	30	PAR	Peng et al. 2012	1			0	0	0
Trinil	Indonesia	Shell	1	LP	540-430	ZZ; PAR	Joordens et al. 2015	1			?	0	0
<b>Total</b>			<b>608</b>					<b>36</b>	<b>49</b>				

\* CC: Criss-cross; CH: Cross-hatching; CHB: Cross hatched band; Ch/Qt: Charentian – Quina type; CL: Curved lines; CO: Concentric lines; EUP: Early Upper Paleolithic; FL: Fan-like; HB: Hatched band;

LP: Lower Paleolithic; MP: Middle Paleolithic; M: Mousterian; MSA: Middle Stone Age; OES: Os-trich egg shell; PAR: Parallel lines; PM: para-Micoquian; PMK: Parallel marks; SPL: Sub-parallel lines; ZZ: Zigzag.



Figure 2. Ochre pieces from Blombos Cave phase M1 (top and middle) and Klasies River Cave 1 (bottom) on which engravings were made on facets previously flattened by grinding (photos F. d'Errico)

### **Putting Neurovisual Resonance Theory to the test**

The functional sub-regions of the low-level visual cortex (V1, V2, V4) to which Hodgson attributes a key role in his Neurovisual Resonance Theory treat an array of single or variously associated properties of visual information, including those linked to the patterns that Hodgson considers to be “perceptual primitives”. In other words, as far as present-day humans are concerned, the function of the primary visual cortex in general, and of these sub-regions in particular, do not provide, in and by itself, any support to the hypothesis that in archaic hominins or early modern humans the primary visual cortex facilitated the fixation of these patterns and their “materially-engaged intentional exploitation”. Since we cannot conduct experiments on the perception of visual stimuli by the brain of archaic hominins and early modern humans, and since – according to Hodgson – even illiterate observers would not represent an acceptable match, one might suspect that NRT is not, a scientifically testable theory. Contrary to Hodgson’s stand, however, we propose that means to empirically test NRT can be implemented, and we feel supported by the growing number of researchers who have been applying neuroimaging techniques to Modern Humans in order to test hypotheses on the evolution of cognitive functions (Stout & Chaminade, 2007; Stout, et al., 2008; Stout et al., 2015; Putt et al., 2017; 2019) would probably, like us, favour the second approach.

Inferring cognitive abilities of fossil human species from the functional study of the modern human brain is, of course, not an easy task. Regarding the visual cortex, however, anatomical-functional differences do not probably represent a main bias. Evolution does not seem to have profoundly modified its structure (Ponce de León et al., 2016; Holloway et al., 2018). The study of functional homologies between monkeys and humans points to a preservation of major functional subdivisions, at least with regard to low-level visual areas and the ventral pathway (Orban et al., 2004).

Since anatomical similarity does not entail similar function, a number of research strategies have been created, depending on the research goal, partially to overcome the problem of experimenting with present-day individuals. One is to conduct experiments with illiterates (Dehaene et al. 2010, 2015), who are, however, more and more difficult to assemble. Another is to contrast the response of expert and non-expert individuals or to conduct experiments on the same individuals before and after the acquisition of a given skill (e.g. Stout and Khreich 2012; Hecht et al. 2014). Still another, adopted by Mellet et al. (2019), is to contrast the perception of different visual categories (objects, symbols, words, outdoor scenes, early engravings) with their scrambled versions, i.e. the randomly decomposed versions of the same stimuli (Figure 3). The advantage of this approach lies in the possibility it offers to map the brain regions sensitive to the global structure of each stimuli and compare them to those elicited by visual stimuli in which such global organization has been removed. It is interesting to note here that scrambled images of early engravings *do include* vertical and horizontal juxtaposed lines, junctions and crossings, i.e. the patterns that, according to Hodgson, would be frequently found in the environment that the primary visual area (PVA) is biased towards, and hence would have been “distilled” to produce the earliest graphic representations.



Figure 3: Tracing of an engraved ochre from the Klein Klipuis, South Africa (left), and its scrambled version (right), which served as reference condition in the experiments conducted by Mellet et al. (2019).

However, the untested NRT prediction that “precisely because they are realised in a pure distilled form, elemental geometric marks activate neurons in the early visual cortex with greater vigour than visual information from the natural environment” (Hodgson, 2019, p. 589) is not confirmed by Mellet et al.’ results: the contrast “perception of engravings” minus “perception of their scrambled versions” did not reveal any activation in the PVA. This means that this area was not more activated by the tracing of the engravings than by their scrambled version and was not particularly sensitive to the global organization of the engravings. This result does not support Hodgson’s statement according to which “it is the ordered structural properties of the engraved patterns to which the early visual cortex is responding” (Hodgson, 2019, p. 591). Rather, Mellet et al. results emphasize the role of more anterior visual regions belonging to the occipito-temporal pathway in the processing of the engravings. It is in these regions that a strongly unbalanced response in favour of the tracings of the engravings compared to their scrambled version is actually found (Figure 4).

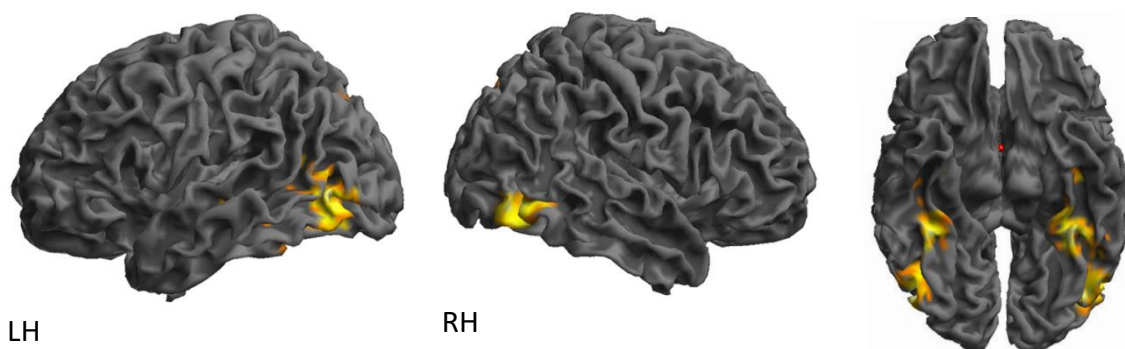


Figure 4: Lateral and inferior views of the activations elicited by the perception of engravings located in the occipital lobe and the ventral part of the temporal lobe (displayed at  $p < 0.001$ , uncorrected. LH: left hemisphere, RH: right hemisphere).

NRT emphasizes the role of natural scene perception in the emergence of engravings production. In this respect, it is noteworthy that the perception of outdoor scenes included in Mellet et al.’s protocol did not involve PVA when compared to scrambled outdoor scenes and gave rise to a profile of activation along the ventral pathway that is very different from the one exhibited by the perception of engravings. In agreement with existing literature, perception of outdoor scenes produced activations in the parahippocampal cortex (i.e. the parahippocampal place area), the posterior cingulate, and a region of the occipital cortex corresponding to the so-called “occipital place area” (Epstein and Higgins, 2007; Çukur et al. 2016). Thus, Mellet et al.’s results indicate no perceptive relationship between engravings and outdoors scenes. This does not support the claim that “the first

geometric marks made by hominins seem to be composed of such distilled topological configurations precisely because they were fundamental to perceiving the natural world” (Hodgson, 2019, p. 589).

An interesting point raised by Hodgson is that the participants in Mellet et al.’s study were literate, i.e. experts in deciphering letter and graphemes, and in transforming them in a phonological format. This may have influenced the regions mobilized by the perception of abstract engravings. The question is legitimate as the experiments elicited an activation of a region corresponding to the VWFA. Does this mean that these literate participants implicitly perceived the engravings as an “unfamiliar orthographic system” as suggested in Hodgson’s article? It should first be noted that, while the VWFA is known to be crucial for reading, it is also involved in the processing of other visual categories (Price and Devlin, 2003; Vogel et al. 2012 and 2014). Mellet et al.’s protocol included a condition of symbol-perception (chains of characters of the Linear B writing system) compared to the perception of their scrambled version following the same logic described above for engravings. Rather than just looking at the activity in VWFA, Mellet et al. compared the profile of activation of engravings and symbols along the ventral visual pathway. Although some regions were activated in similar ways, the processing of these two categories of stimuli gave rise to a quite different profile of brain activation along the ventral pathway, making unlikely that the engravings were perceived as an unknown orthographic system.

We can even go further since our study also included a condition of word perception. When compared to the perception of engravings, we found that VWFA was the only region activated alike by engravings and word perception, the other regions responding very differently. In particular, unlike the perception of engravings, the perception of words involved areas classically described in previous studies (Jobard et al. 2003), including VWFA, superior and middle left temporal areas, and left inferior frontal gyrus (at  $p < 0.05$  uncorrected for this latter region), all of which are strongly left lateralized. This result suggests that the functional specificity for word reading does not rely on a single region but on a left lateralized network (Jobard et al. 2003; Price and Delvin 2003). Thus, looking at the whole profile of activation rather than focusing on a single region reveals that, although participants were literate, the pattern of activation for engravings and word perception strongly differed. This supports the hypothesis that the participants’ literacy was not a confounding factor.

## **Conclusion**

The earliest engravings are generally considered, together with the use of pigments, ornaments and mortuary practices, as reliable archaeological proxies for the emergence of symbolic material cultures in our lineage. This assumption is based on the observation that comparable abstract representations were used for symbolic purposes by historically known populations and that these innovations are found, at some archaeological sites, together and in association with other innovations such as sophisticated bone and stone tools. This view is reinforced by detailed analyses of the engravings demonstrating their not utilitarian, deliberate nature. It is also supported by the discovery of similar patterns produced with different techniques and on different media at the same site. However, these facts do not constitute a final proof that all the earliest abstract engravings discovered to date bear witness to symbolic practices, especially considering the chronological gap that exists between some of them and the first figurative representations. Moreover, even in cases in which the symbolic hypothesis is supported by multiple reasons, it does not inform us, in itself, about the way in which these representations were perceived by those who produced and observed them. The hypothesis, postulated by NRT, that the primary visual area played a central role in the emergence of abstract

graphic productions is not confirmed by the study of brain activity during the perception of the earliest engravings. Rather, our results support their processing by areas of the brain dedicated to specialized functions and in particular by cortical regions involved in object identification. These results are consistent with the hypothesis that these representations played symbolic functions. Although research questions and strategies need to be sharpened in the future, the path is open to empirically investigate the perception of early engravings by the human brain and explore their significance for hominin cognition.

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## Legends of figures

Figure 1. Sets of subparallel cut marks on bone remains from Linjing, China (photos F. d'Errico). Scale = 1cm.

Figure 2. Ochre pieces from Blombos Cave phase M1 (top and middle) and Klaisies River Cave 1 (bottom) on which engravings were made on facets previously flattened by grinding (Top and Middle: photos F. d'Errico/ Henshilwood, bottom: photo F. d'Errico)

Figure 3: tracing of an engraved ochre from the Klein Klipuis, South Africa (left) and its scrambled version (right), which served as reference condition in the experiments conducted by Mellet et al. (2018).



Figure 4: Lateral and inferior views of the activations elicited by the perception of engravings located in the occipital lobe and the ventral part of the temporal lobe (displayed at  $p < 0.001$ , uncorrected. LH: left hemisphere, RH: right hemisphere).

#### **Legend of table**

Table 1. Occurrence of accidentally made marks and natural patterns on objects bearing the earliest known engravings