Uses and Abuses of the Enhanced-Working-Memory Hypothesis in Explaining Modern Thinking

by Manuel Martín-Loeches

Evidence is reviewed here that is contrary to the idea that a small enhancement in working-memory capacity determined the emergence of the modern human mind as something radically different from previous human minds and materialized only in figurative art, particularly therianthropes. When reviewing the neurological and psychological literature on working memory, it is clear not only that working-memory capacity varies extensively within modern populations but also that working memory and general intelligence are becoming highly synonymous. In this conception, working memory could appear less obscure, and the idea of a gradual increase in working-memory capacity along the human lineage would appear to be a parsimonious scenario. In a different vein, the neurological underpinnings of art are reviewed. The geometrical engravings from Blombos Cave, as old as 100,000 years, appear to probe the presence of art in its plainest sense in Africa by that time, much earlier than the emergence of therianthropes in Europe during the Upper Paleolithic explosion of art. Noticeably, the Blombos Cave engravings have much in common with present-day art. The possibility that most therianthropes are the result of an unsuccessful attempt to merely draw animals is also discussed.

q1 An enhancement of the working-memory capacity (enhanced working memory [EWM]) appears to be a parsimonious and sound proposal for explaining modern thinking. However, as it was originally outlined, this hypothesis conveyed (even if only implicitly) the radical idea that it was intended to be *the* solution to the humankind enigma. In this regard, Coolidge q2 and Wynn's line of reasoning appears to suggest that EWM implied a sudden and totally new change in human cognition, accounting for the advent of an unprecedented mind on Earth. This "revolution" would have occurred in Europe about 30–40 kya, and as a result, art and religious thought would have emerged, giving place to a cultural explosion during the Upper Paleolithic (Coolidge and Wynn 2005, 2006).

In my view, however, Coolidge and Wynn may have overlooked several lines of evidence against a truly abrupt and qualitative transformation of the human mind. It will be the main purpose of this article to comment on this evidence in light of the EWM hypothesis. Accordingly, I will review some data indicating that the improvement occurring in the human mind that gave rise to modern thinking might have been a minor one adding to already attained previous advancements within the genus *Homo*. As an outcome, the achievement of the modern mind would have been a gradual phenomenon rather than a sudden one, the border between the modern and the nonmodern mind being highly indefinable. Furthermore, I will review evidence revealing that the emergence of the modern mind (admittedly, a mind that has been categorized in such a way) could have arisen long before the Upper Paleolithic explosion 30–40 kya in Europe. Instead, a better time and place would be some 100 kya in Africa. Moreover, it also appears probable that the modern mind did not come to a dead end after emerging in Africa by that time but underwent further enhancements throughout subsequent years, including current times.

Conceptions of Working Memory

There are various ideas about what working memory is. By collecting several proposals, we could arrive at a comprehensible, simple, and schematic conception of working memory as follows. First of all, from the neurological point of view, working memory is understood as the sustained neuronal firing selective to a stimulus feature no longer present in the environment but needed to be kept over short periods of time for immediate access and evaluation (Compte 2006). This has

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also been known as persistent activity, which has been reported for many brain cortical areas (Fuster 1995; Goldman-Rakic 1995) and which appears to be involved in tasks other than working-memory tasks, such as oculomotor coordination and head-direction movements (Major and Tank 2004). It appears, therefore, to be a general computational strategy developed by the nervous system.

This depiction is based mostly on animal research. When working memory has been applied to human cognition, however, it has usually gone beyond the persistence of activity representing perceptual features by also engaging the persistent activation of knowledge stored in long-term knowledge. The latter would comprise specific knowledge (facts stored in both episodic and semantic memory) as much as computations needed to process information and the outputs of these computations (MacDonald and Christiansen 2002). Overall, the main idea is that working memory implies the persistent (though always transient) activation of neural circuits representing stimulus features, long-term knowledge (including computational rules or algorithms), and the results of the computations performed so far.

Keeping this conception of working memory in mind (more properly, in our working memory), it might be easy to understand that EWM appears synonymous with enhancing the number of persistently activated neurons on behalf of a particular task, that is, an increase in the number of neurons that can be activated simultaneously (Aboitiz et al. 2006; Martín-Loeches 2006). Accordingly, the genetic mutation that gave rise to the final achievement of EWM could have occurred via one of the following possible causes for this phenomenon or a combination of them (indeed, they are not mutually exclusive): (*a*) an increase in the number of neurons available and/or of the complexity of the neural circuits involved (Coolidge and Wynn 2005); (*b*) the possibility of using additional metabolic resources for keeping active a larger number of neurons (alternatively, the possibility of decreasing the metabolic costs of keeping neurons activated so that more neurons can be activated with the same total costs; many possibilities could be raised here, such as increases in the synaptic efficiency both at pre- or postsynaptic levels [e.g., Balter 2007]); (*c*) a prolongation of the (decay) period of neuronal firing following activation boosts, a relevant feature of working memory for computational purposes (Lewis, Vasishth, and Van Dyke 2006).

Because working-memory capacity appears to be a highly heritable trait, this has been taken as support for the proposal by Coolidge and Wynn (2005) that a single additive mutation could have been responsible for EWM. However, the number of genes contributing directly or indirectly to working-memory capacity may be large. Indeed, many of the genetic differences between our closest relatives, the chimpanzees, and our species appear to be related to genes involved in processes with direct or indirect consequences for working memory. For example, two genes involved in neural cell proliferation (ASPM and MCPH1) and related to the number of existing neurons have undergone an accelerated evolution in the human lineage and, what is more, continue to evolve adaptively in humans (Evans et al. 2005; Mekel-Bobrov et al. 2005). This is also the case for the gene NRCAM, which participates in the regulation of neuronal connections. Several other genetic regions relevant to this feature are called "human accelerated regions" and relate to interneuronal connections, namely, by expressing cadherines (proteins involved in cell adhesion, i.e., synaptic contact; Prabhakar et al. 2006). Additionally, certain genes, such as SIGLEC11, involved in glial expression (affecting neural metabolism and synaptic processes) have been found to be human specific (Hayakawa et al. 2005).

Another good candidate for contributing to working-memory enhancement has been, traditionally, the FOXP2 gene. Anomalies of this gene may cause both structural (number of existing neurons) and functional (number of activated neurons) abnormalities in certain brain regions related to language (Vargha-Khadem et al. 1998). However, the recent finding that this gene was shared with Neanderthals (Krause et al. 2007) certainly rules out the possibility that this gene was responsible for the final achievement of modern thinking.

As can be seen, there are a number of genetic candidates for the development of EWM. Accordingly, considering genetic evidence and in the light of the working-memory definition from the neuronal point of view outlined previously, the idea of an abrupt change in the human mind appears to be somewhat misleading. Instead, it would be more plausible to consider the idea of multiple and successive enhancements in working memory along the human lineage. Furthermore, because some of those relevant genes appear to be still evolving, there is the possibility that our mind has further evolved since it became modern and that it is still evolving. Consequently, I suggest that there have been successive, gradual, and probably subtle enhancements of working memory, with multiple factors contributing to this end, since human and chimpanzee lineages ultimately diverged. q3

Indeed, if we agree that modern *Homo sapiens* is the most intelligent creature on Earth (which is actually commonplace, tautologically included within the name *H. sapiens*), we have to accept that modern *H. sapiens* is the creature with the largest working memory on Earth. Both intelligence and working memory are becoming relatively synonymous in contemporary psychology. Recent proposals stress this intimate relationship, if not entire overlap, between working memory and intelligence (Colom et al. 2004; Unsworth and Engle 2007). Accordingly, if we agree that modern human intellectual ability has been the consequence of a gradual process of evolution, we must also agree that EWM has been attained gradually. It appears plausible, therefore, that EWM was achieved following multiple genetic mutations, none of them more outstanding than the others, and the border between modern and nonmodern minds becomes rather blurred.

How could EWM explain the modern mind? Let us examine the case of language as a representative example. With an enhancement in working-memory capacity, human lan-

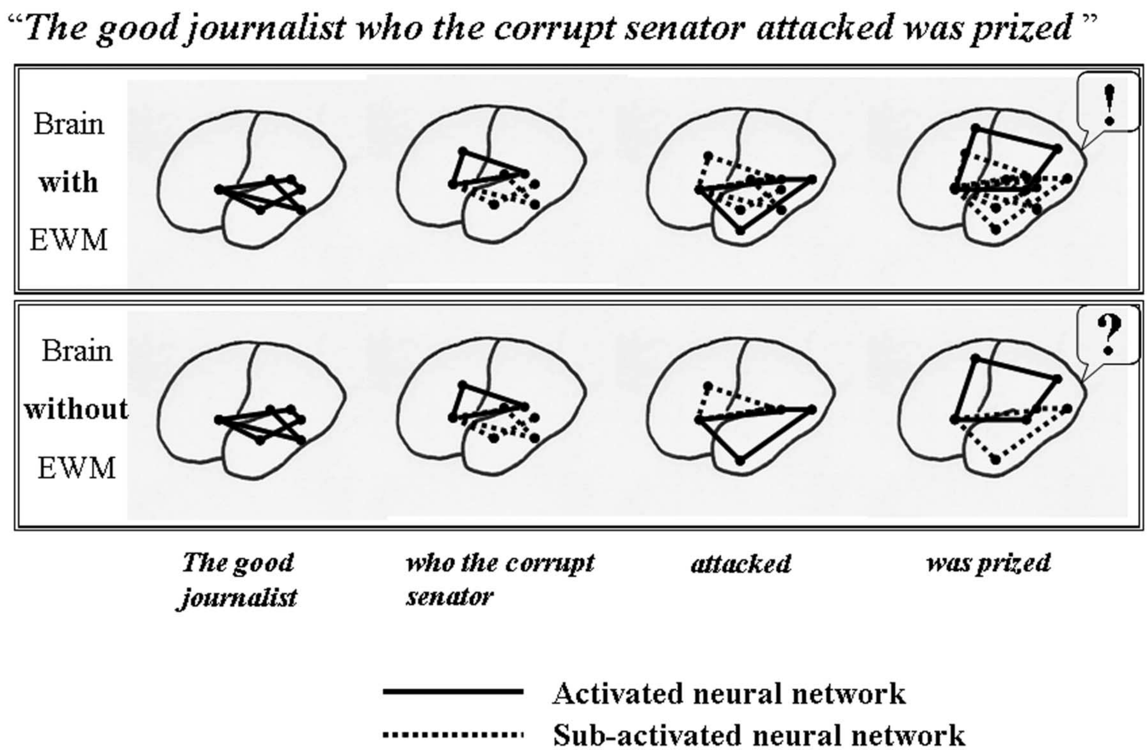

Figure 1. The neural network with enhanced working memory can successfully decode the sentence, but the network without enhanced working memory cannot.

guage can be significantly improved, achieving the unique features that characterize modern human language. In this regard, a main central process in human language is the comprehension of sentences. A sentence is composed of several words, and it is the human brain's goal to determine what the relationships between these words are, relationships based on a structure with some degree of hierarchy.

In the sentence "The little cat is beside the big dog," the adjective "little" refers to "cat," and the adjective "big" refers to "dog," whereas both animals have some type of mutual relationship (one is beside the other). This is true even though, and according to the syntactic structure of the sentence, we are primarily speaking about one of the animals ("the little cat," which is the subject of the sentence). Interestingly, this sentence could probably have been understood by a brain with a working-memory capacity less than that achieved by modern humans, for example, a Neanderthal mind, and even possibly others. But now consider the following sentence: "The good journalist whom the corrupt senator attacked was prized." There is a relatively long distance between "was prized" and "the good journalist," together with some disturbing elements in between: another participant ("the corrupt senator") and another verb ("attacked"), regardless of which we have no trouble in recognizing "the good journalist" as the subject of the main sentence and "was prized" as the main verb in the sentence, attaching this verb to that subject. A Neanderthal probably could not understand this sentence, given that it is both long and contains relationships between the words that are nonlinear. To understand a sentence as the latter (as well as notably longer and more complex examples that could have been brought up here), we need the working-memory capacity of modern humans. With EWM, we can (easily) keep activated or subactivated several elements in working memory until they are attached or related to their corresponding counterparts even if there is distance between them and confusing elements appear in between (fig. 1).

By having a complex language able to define complex relationships of the real world, we have a tremendously powerful tool to better comprehend the complexities of the real world. In other words, we would have an improved way of reasoning. However, this does not necessarily mean that it is language that improves thought (e.g., Pinker 2007). Instead, an increase in working-memory capacity could be a general-purpose neural mechanism explaining both a better reasoning capacity and complex modern language.

Before going on, I think it is crucial to outline a last reflection on working-memory capacity if we want to better define what EWM might actually mean. It is important to perform systematic studies comparing our working-memory capacities with those of our closest relatives, the chimpanzees (though other species could also be good enough). This is work to be done. Indeed, we have several parameters to focus on. For example, does our EWM imply that we can keep in our working-memory store a higher number of items than monkeys can? Or can our EWM keep a similar number of items but the quality and/or complexity of each item can be larger in our species? The answer may indeed depend on the type of knowledge to be retained. A recent discovery by Inoue and Matsuzawa (2007) shows that chimpanzees can be even better than us in remembering visuospatial sequences of numbers. Whatever the answers to these questions, how long is the decay time of stored items in each species? Could it be (as well) that our items are kept longer? Does the duration parameter also depend on the type of information to be stored and manipulated? Specific answers to these questions will assist us with defining in depth what EWM means for modern thinking.

Markers of Modern Thinking: The Special Case of Art

Regardless of whether the modern mind was achieved gradually or suddenly, it cannot be denied that it appears as qualitatively different from previous human minds. There are some features of modern human thinking that appear distinctive. Several of them have been shown to appear in Africa over 200 kya. These include the manufacture of points, grindstones, and blades as well as pigment processing (McBrearty and Brooks 2000). Some others, such as the use of bone tools, mining, or fishing, are more recent achievements but again far from the 30–40 kya proposed for EWM (actually, closer to 90 kya). This evidence supports a gradual achievement of modern thinking.

Perhaps one of the most outstanding and recently achieved features of our mind is the production of art. In the following, I will focus on this feature in depth because it constitutes evidence that EWM could have been a matter of gradual achievement and that it might have arisen long before 30–40 kya out of Europe.

Contrary to the classical hypothesis that a human revolution occurred in Europe by 30–40 kya, yielding both art and religion as a main outcome (together with other distinctive achievements), art and religion might be two different and distinguishable phenomena that might have arrived independently. Yet art appears to leave a more clear signature in the archeological record. Is this the final evidence for modern thinking? The answer may depend on our conception of art.

Coolidge and Wynn (2005) suggest that even if earlier samples of art have been found, the modern human mind did not arrive until therianthropes appeared in Paleolithic art about 30 to 40 kya in Europe. These drawings, which mix human and animal features, would be evidence, according to these authors, that a modern mind able to combine different entities had been achieved. This disregards other types of art, such as geometrical patterns or depictive images, as probing the presence of modern thinking. Accordingly, geometrical patterns and depictive images would be a product of a premodern mind. However, the evidence to support this assertion is not as strong as it appears. The geometrical patterns of Blombos Cave, as old as 100 kya, could probe the presence of art in its plainest sense. To support this argument, we need first to take a look at what cognitive neuroscience tells us about art.

Ramachandran and Hirstein (1999) outline a basic idea: art produces pleasure. For every piece of art, the artist, consciously or not, would make use of some procedures that better and pleasantly excite the perceptual areas of our brain. Visual art would be a good tool, accordingly, to overexcite visual brain areas. Hence, to be considered artistic, a piece of art must overexcite perceptual areas more than natural stimuli, and by this means, it should evoke pleasure to the perceiver. The proposal by Ramachandran and Hirstein has been recently endorsed by a number of authors (e.g., Smith 2005)

This overstimulation of perceptive areas would produce pleasure as a consequence of the direct neural connections between those regions and the limbic system, the brain system for emotions. One basis for this state of affairs is the fact that our cognitive system is well suited to feel satisfaction, or emotional responses, whenever something relevant in the environment is discovered. To discover a prey, or a predator, hidden in vegetation (or far away and therefore hard to see) would represent a success to our perceptive system, and, consequently, it would trigger an emotional response. It is a basic survival mechanism. For this reason, both our system for reasoning and decision making and our emotional system are closely related. Art might take advantage of this mechanism.

Ramachandran and Hirstein (1999) propose eight principles by virtue of which art exploits this mechanism of overexcitation of our perceptual system that produces pleasure. It is worth making a brief comment on these principles here. Overall, it has to be remarked that all of them are purely perceptual principles.

The first principle is exaggeration: exaggerated attributes are more strongly appealing than normal ones. "Supernormal" stimuli, as caricatures or nude bodies with larger-than-real sexual attributes, as is the case of prehistoric Venuses, would powerfully summon our attention. The second principle states that if one of the features of the stimulus (as shape or color) is emphasized, the stimulus will be more rewarding because all of our attention can more easily focus on that feature. As an example, many artistic pieces are black and white or, even more often, made just outlining a shape. Indeed, a vast majority of Paleolithic art consists of outlined shapes, and these include the certainly profuse engravings. The third and forth principles directly relate to our capacity to detect figures against background. In this regard, the third principle states that grouping several elements of the perceptive field (e.g., dots) as constituting parts of a single entity leads us to discover "hidden" figures and, hence, to attain some degree of pleasure. The fourth principle stresses the relevance of exaggerated contrasts in the stimulus, which facilitate the detection of individual figures.

The fifth principle deserves further comment. It is probably one of the most intriguing, having been highlighted also by other authors (Zeki 1999). According to the fifth principle, resolving perceptual problems is rewarding. That is, whenever our perceptual system has to undertake an effort in order to completely understand a stimulus, pleasure is assured. For this reason, an incomplete nude figure may be more appealing than a totally nude one, because it is our brain that completes what is not visible (but just suggested). Also for this reason, many figures are not detailed, and even many incomplete artistic items can be found. This has in fact been alleged as a reason why Michelangelo did not finish several of his most notable masterpieces: what Michelangelo had in his mind could not be represented in the real world because it may have been more perfect than anything in the real world (Zeki 1999). Beneath this principle is the idea that one of the main purposes of our brain is to seek constancies and essences, to seek relevant points. This is not an artistic ability, indeed, but rather an overall cognitive one, one of the main goals of our cognitive system. However, even if discovering these essences is based on numerous perceptual experiences, its outcome is not perceptual in nature, and, therefore, it is not easy (if at all possible) to retrieve it to the real world in the shape of an actual depiction, engraving, or sculpture.

For instance, a chair is a chair even if it has four, three, or even one (big) leg or whatever the color and material it is made up of. In fact, many variants in shape, or any other visual feature, could be brought up here, but a chair would still be a chair despite these variations. For this reason, it would not be easy (if at all possible) to draw the "essence" of a chair. This same (fifth) principle would also apply when we are able to "discover" figures out of the clouds, much as when Paleolithic artists "saw" figures in the rock walls where a piece was going to be outlined using natural edges and shapes as parts of paintings or engravings. Overall, perception is always a process in which bottom-up and top-down processes interplay constantly. That is, perception is the result of both what is actually before our eyes and our previous knowledge of the world. Art exploits to a high degree top-down processes involved in perception.

Ramachandran and Hirstein (1999) propose three more principles essential to art. According to one of these, generic visual interpretations are preferred to concrete or very specific representations (this principle indeed relates to the previous one). Another principle states that metaphors would be preferred because these mark and stress specific aspects of reality that can hardly be seen at first sight. Symmetry is a matter of the last principle: symmetry is appealing for us, usually as an indicator of health and perfection.

As can be seen, all the principles proposed by Ramachandran and Hirstein (1999) have as a common element the fact that art is more appealing the greater the extent to which it outweighs reality, the extent that it goes further than the real world. When this happens, our attention is strongly summoned, and we feel pleasure.

After considering these principles, it appears evident that, together with perceptual areas and limbic regions of the brain (devoted to perception and emotion, respectively), art must involve the prefrontal cortical regions. Indeed, one of the main nuclei within the limbic system is the amygdala, which in turn has strong connections to our intellectual system in the prefrontal lobes, including the dorsolateral prefrontal cortex and the anterior cingulate gyrus, the system that permits us to plan, anticipate, and decide (De Martino et al. 2006). Interestingly, these regions have undergone accelerated evolution in the human lineage and/or display a particular neural organization in the primates, particularly in humans (e.g., Schoenemann 2006). These regions play a principal role in the coordination of the work of posterior (perceptual) brain regions and also resolve what is relevant and what is not relevant. Furthermore, they are crucial to extracting the "essences" of the perceived world, a core purpose of art. For these reasons, it is not unexpected to find studies in which the dorsolateral prefrontal cortex plays an outstanding role in beauty perception (Cela-Conde et al. 2004). If art produces pleasure, and if this pleasure is closely linked to brain areas strongly responsible for our highest levels of intelligence and working memory (e.g., Kane and Engle 2002), it is far from surprising that a species with such a degree of intelligence and working memory as ours gave rise to art eventually.

Accordingly, the emergence of art required the expansion of certain regions of the brain: the perceptual and prefrontal cortical areas as much as the cingulate gyrus. These regions have, in turn, a core role in consciousness, in both its perceptual and volitional facets (e.g., Lamme 2006). This agrees with the assertion by Solso (2003) that only a mind with a high degree of consciousness—able to voluntarily manipulate a large amount of information simultaneously (this is a good definition for working memory)—can generate art (Solso 2003). This may be why only humans have art.

However, the expansion of these regions and the achievement of higher levels of consciousness and working memory were certainly not sudden processes. Rather, they were the result of progressive evolution along the human lineage. This might be the reason why samples of possible, even if uncertain, art expressions can be found belonging to periods long before the supposed appearance of the modern human mind, such as the controversial Berekhat Ram figurine, dating more than 300 kya. Perhaps we should not disregard other ancient signs of beauty or "art sense," for example, the apparently senseless symmetry of the handaxes designed as long ago as those by *Homo ergaster*. Indeed, it is not hard to appreciate their beauty, and they might be accepted as rudimentary pieces of art. What is more, they are exploiting one of the principles established by neuroscientists as belonging to art. Symmetry in handaxes is not a fortuitous "artistic" expression; it is due neither to chance nor to the result of natural factors. Even if rudimentary and acceptably incomplete as art, we already have some of the art principles present in very early times.

Several other artistic signs are more ambiguous, such as the engravings found in Bilzingsleben, Germany. The four bones displaying a series of parallel lines that could actually be the result of the use of tools to extract meat out of bones. In Zhoukoudian, close to Beijing, 20 pieces of quartz with no apparent use were found to have been collected by *Homo erectus*. However, it is true that some birds also collect bright objects.

Although controversial and debatable, these and other possible art samples may have been in place before the emergence of the modern mind. But it is also true that apart from intentional symmetry, they all are dubious and could be interpreted as the result of fortuitous circumstances, not as deliberate artworks. Part of the scientific community, nevertheless, strongly supports the validity of several of these ancient pieces as true art. I am personally not among them, but I do believe that the existence of debates and doubts about these products shows that the border between the absence and the presence of art may indeed be indefinable. This would in turn support my suggestion that the achievement of our high levels of working memory and consciousness, necessary to yield art, was a progressive accomplishment.

There are ancient pieces of evidence that cannot be the product of chance or natural variables, and these are clearly the product of a modern human mind. Some of them are as old as 100 kya and were produced in South Africa, much earlier than the proposed emergence of the modern mind about 30–40 kya in Europe. The Blombos Cave engravings on ochre stones might conform to a tradition occurring over a period of 25,000 years that consisted of crosshatched designs, dendritic shapes, parallel lines, and right-angled juxtapositions (Henshilwood, d'Errico, and Watts 2009). These engravings appear to be deliberate (i.e., not incidental marks secondary to utilitarian processes), and they indicate precise neuromotor control (Henshilwood, d'Errico, and Watts 2009; Henshilwood and Dubreuil 2009). But interestingly, the Blombos Cave engravings also meet the requirements to be considered art. Noticeably, in this regard the Blombos Cave engravings excite our more primary perceptual areas of the visual system. Cortical regions in Brodmann areas 17 and 18 (occipital regions, the first processing landmark in the cortical visual system) are particularly specialized for seeking linear patterns in the environment and fit well those appearing in the Blombos Cave engravings. In this sense, therefore, the Blombos Cave engravings might be overstimulating our primary visual areas, and their contemplation may evoke in us
q4 the same pleasure that it evoked in their creators. This is art, at least according to a neuroscientific perspective. What is more, we have closely similar pieces of art in current times, such as some works by the artist Jesús Rafael Soto and certainly many others. In summary, there is the argument that
q5 the Blombos Cave engravings may suggest an early stage in art production before the emergence of figurative art and therianthropes and, therefore, before the modern mind. Alternatively, there is my present argument that the Blombos Cave engravings meet the neuroscientific requirements of art and, therefore, that figurative art, therianthropes, and these engravings are produced by the same modern minds.

However, to better depict the whole picture, we need to fill the gap between art produced some 100 kya and the Chauvet paintings of some 32 kya if we do not want to disregard the latter as reflecting the true onset of a human mind revolution. We also need to explain why the amount of art noticeably proliferated that much by 30–40 kya in Europe. This, which has been considered as evidence for a mental revolution, could rather be the result of other circumstances. Let me attempt to fill this gap.

Indeed, several partial pieces of evidence seem to indicate that from 75 to 30–40 kya, there is not a complete gap. In Kostenki, Russia, the remains of a human population as old as 45–42 kya have been recently found (Anikovich et al. 2007). These findings comprise what may be considered the oldest known sculpture so far: a bone fragment possibly representing an unfinished human head. I would not go so far as to assert that the figurine was unfinished for the same reasons that compelled Michelangelo to leave unfinished several of his sculptures, but I do believe that this is evidence that the modern mind did not suddenly emerge in Europe only 30–40 kya.

The same modern human population that dispersed from Africa some 80–60 kya (Goebel 2007; Mellars 2006) was probably the one traveling to Australia by 60 kya or even earlier. There are ochre remains in caves of Australia produced by that time and even some geometric patterns that might also be that old (Flood 1997). What is more, much of the subsequent art production in Australia displays striking resemblances to European art occurring after the hypothetical human revolution, including handprints on the walls. We humans of nowadays have lost the knowledge of the reasons for these handprints, but it is interesting that human populations located at opposite ends of the world used handprints in similar time periods: Australia is just at the antipodes of the places in Europe where the art revolution (and, then, the hypothetical last enhancement in working memory) supposedly took place. This rather suggests that a common population using handprints and other commonplaces of Paleolithic art appeared elsewhere and, from there, it expanded to Asia, Europe, and Australia. Other possibilities imply calling for human universal art archetypes, but this is certainly not a solid argument even if it is admissible.

Nonetheless, it is true that dating the oldest Australian art is still a controversial matter, and more research is needed in this regard. Accordingly, it could not totally be discarded that later populations migrated from Europe to Australia, giving place to Australian art, but this is certainly not a parsimonious possibility.

I assume, therefore, that the modern mind was already present in Africa at least some 100 kya and from that place it expanded to other places, including Europe and Australia. However, we should explain the explosion of European Upper Paleolithic art that took place some 30–40 kya. Disregarding the possibility that the human mind suffered a radical change or improvement by such time in Europe, I prefer, as others have, to call it a cultural explosion. That is, there was a revolution in the amount of art, not in the quality of art (and, therefore, not in the quality of the minds of the artists as a consequence of an exceptional genetic mutation); it would have been an overwhelming production of art.

To explain why so much art appeared in Europe by some 30–40 kya, local circumstances can be brought into play. In principle, although a final working-memory enhancement can not be totally rejected, other plausible and more parsimonious explanations fit. One is, of course, the presence of particular taphonomic circumstances by virtue of which the relative abundance of caves in Europe provided not only good canvas for Paleolithic art but also excellent preservation conditions. But several other complementary explanations are possible. For instance, Lewis-Williams (2002) has proposed that the abundance of art in Europe by this time is mainly a consequence of our encounter with Neanderthals. In this sense, a large amount of art production would have been used as a way of demonstrating the intellectual superiority of our species, as an attempt to impress our closest evolutionary relatives. Another possibility, stressed by Guthrie (2006), is that most of the Paleolithic art in Europe was created by teenagers. Indeed, given the quality and the content of most of the art from that period, as well as the size and the shape of the numerous handprints found in the cave walls, Guthrie convincingly argues that the creators of most European Paleolithic art were indeed teenagers. In this view, good-quality art would be an exception, not the rule, and a demographic explosion would be the most plausible reason accounting for that art explosion.

However, we have a pending matter: therianthropes. Guthrie, who is not only a natural historian but also a skilled sculptor, claims that most of the production of theoretical therianthropes is the result of failed attempts to represent animals and not human-animal mixtures. Accordingly, most (if not all) therianthropes are in fact the products of bad and inexpert artists attempting to draw animals and only animals. What appear to be human bodies or legs together with animal heads or other body parts are rather the result of a mistaken observation of the real shape of the body parts of the represented animals. Even several of the most well-known therianthropes, such as the famous “shaman” from Trois Frères in France, could be explained in this way. Although there is substantial criticism of Guthrie’s claims (e.g., White 2006), I find his interpretation of therianthropes plausible and parsimonious.

Consequently, real therianthropes would be the exception and not the rule. Is this exception enough evidence for the emergence of a different mind with an EWM relative to that of the creators of the Blombos Cave engravings? From my point of view, therianthropes are not a strong argument for a final EWM occurring 30–40 kya in Europe because more plausible and parsimonious explanations are available. This is also the case for the vast increase in the amount of art in Europe occurring at this time. And at the least, neither therianthropes or the increase in art in Europe at that time is a strong argument for a qualitative change in the human mind.

A final comment regarding the comparison of the Blombos Cave engravings with therianthropes deserves some space. Indeed, therianthropes (and figurative art in general) would be stimulating cortical brain areas devoted to higher (i.e., deeper) levels of information processing than those excited by the Blombos Cave engravings. In this sense, the existence q6 of an evolution of the depth of processing involved in art could be claimed, and, in line with this, an evolution of the mind of the artists could be assumed. Although admissible, this should not necessarily be the case, because as we have seen, modern (current) artists also exploit the overexcitation of primary visual areas. Moreover, there are many primitive societies, even several currently extant cultures, living without figurative art expressions, not to say therianthropes. This is the case of the tribal people in Amazonia, as well as of people from many other places throughout the world (Levinson 2006). Rather, geometrical drawings are instead the rule in many societies. Are they premodern humans?

Last Reflections and Concluding Remarks

Despite all my arguments, I could find admissible the proposal that moving from the Blombos Cave geometrical engravings to figurative art and then to therianthropes suggests different milestones in the evolution of an EWM. But this trail, if real, could better support a gradual evolution of the same (but already modern) mind throughout the millennia. This evolution could be due to both cultural and neurophysiological factors (based on genetic changes that are still occurring) cumulating through time, though each one is of small consequence when considered in isolation. In this line, we should also have to admit that the current human mind is not the same as that of Neolithic times, which in turn would also be different from that of Paleolithic times.

But then, a big problem remains: we should start defining what exactly we mean by a modern mind or modern thinking. With such a definition in hand, we could easily define what a nonmodern mind is. Such a definition might also help us to definitely decide whether the Blombos Cave engravings (and, then, modern art using similar geometrical patterns) are evidence for a fully modern mind. The same would apply to the Russian figurine of Kostenki, to ancient art remains in Australia, or even to figurative art other than therianthropes (provided the latter are real). Overall, it is my impression that it is better to speak of a gradual improvement of working memory and then of intellectual abilities in a process that did not come to an end either in Africa 100 kya or in Europe 30–40 kya; instead, the process still goes on.

As an additional mechanism to be considered as playing a role in this story of gradual improvement, we could mention a proposal by several authors (e.g., Calvin 2004) according to which our cognitive capabilities would have improved from one generation to the next by the fact that a given generation has been exposed to the advances achieved by the previous one, this exposure occurring during early stages in the ontological development. This, by itself, would yield wider and more complex neural circuits when the referred generation becomes adult, achieving cognitive improvements not accomplished by previous generations. These improvements would in turn be transmitted to the next generation, and the cycle starts again. Although the reach of this sort of mental evolution might be somewhat limited if no genetic changes come into play, it could at least explain why the same mind could yield different products throughout the millennia without calling into play the advent of a totally new mind.

In conclusion, it was not one small enhancement but many small enhancements in working-memory capacity, in both the amount and the quality of the material to be stored and treated in working memory, that gave place to the modern mind. These small enhancements produced a rather gradual working-memory improvement and might have occurred relatively often during the whole period since the human and chimpanzee lineages diverged, disregarding a critical landmark or point after which we "crossed a Rubicon" unraveling humankind before and after that point.

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QUERIES TO THE AUTHOR

1 Please confirm that your title and affiliation address are accurate or correct as necessary.

2 Please provide a date citation for Coolidge and Wynn ("2005, 2006"?).

3 I changed "there are a number of genetic candidates to have yielded EWM" to "there are a number of genetic candidates for the development of EWM"; is that okay?

4 I changed "authors" to "creators" here. Is that okay?

5 I changed "imply" to "suggest," but if that alters your meaning, please advise.

6 In the sentence beginning "In this sense...," do my edits retain your meaning?