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ROCK ART, PERSPECTIVAL REPRESENTATION AND MIRROR NEURONS

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Abstract. This article explores possible links between the mirror neurons system and rock art. After a brief review of existing neurophysiological research on rock art, the article describes the mirror neurons system and examines its role in imitation and empathy. It then investigates how empathy affects the representation of animals in rock art. It advances the hypothesis that the depiction of individual animals in profile is indicative of a kinaesthetic empathy, expressing primarily the perception of the animal's bulk, weight, musculature, movement and distance from the beholder. By contrast, frontal representation of an animal figure reveals multiple points of possible sensory response to the animal, entailing a multivalent empathy. This empathetic multivalence of frontal representations also indicates increased engagement of the mirroring system, which, in encoding the observed actions of a frontally positioned animal, triggers a somatosensory process that places a higher threshold on artistic motor skills and kinematic congruence. The demand for kinematic congruence is further heightened by the artist's psychological need to avoid a failed drawing, which may also implicate the inhibitory action of the mirroring system. This modulation of artistic empathy through the excitatory and inhibitory actions of the mirror system, the article concludes, may be responsible for the scarcity of frontal depictions of animals in the rock art record.

A. Neurophysiology and rock art: overview

Among the main concerns of the scientific study of palaeoart is the question of the origin and development of this art. Relating to cognitive evolution, this question has long been the subject of many discussions in *RAR* journal, including the psycho- and neurophysiological aspects of rock art. Thus, for example, Bednarik traces the emergence of rock art to the discovery of iconicity, a development which he connected to the evolution of the human sensorimotor systems and the capacity of producing modulated marks and shapes (Bednarik 1986). Pointing to the developmental role of salience (a perceptual responsiveness to similarity and sensitivity to gradation in the focal position, brightness and boundary contrast of objects), he proposed that most archaic 'art' in the world consists of 'responses to edges or surface aspects, enhancing them or making them more interesting' (Bednarik 1990). The arousal involved in the 'intentional use of visual ambiguity', the 'reshaping of salient aspects of the physical world' and tool-making, he said, 'resulted in an increasing consciousness of the physical reality and a feedback on the mark making behaviour'. It also enhanced the precision of vision-oriented motor skills, as well as the experience of observing intentional impact on the environment through participation. This, in turn, resulted in a proliferation of new neural pathways and the expansion of the associative and conceptual base (Bednarik 1984, 1986, 1990, 2003, 2008, 2011).

Mindful of the co-evolution of lithic technique and cognition, J. Halverson also thought that the 'immemorial practice of stone-knapping provided the motor schema for carving', resulting in the development of the initial figural representation in the form of 'three-dimensional sculptures in the round' (Halverson 1987: 66). These earliest works of 'art', he said, were followed by high and low relief, engraving, and finally painting, a process of 'gradually reducing the dimensionality of the figural representation step by step, from three to two' (ibid.). A further elaboration of the links between rock art and proficiency in tool-making is provided by Lorblanchet, who indicated that stone tools, bifaces in particular, have been the focus of man's creative power, and that the process of shaping lithic stones is, in fact, a 'proto-sculpture' that eventually culminated in artwork (Lorblanchet 2007: 107; also Le Tensorer et al. 2006; Pope et al. 2006; and Achrati 2010, who links the development of sculpture and the use of lithic blades to glaciation).

Noting the salience of symmetry and its correlation with successful ontogenetic development in many organisms, T. Wynn used cognitive archaeology to study the sensitivity of the human perceptual systems to symmetrical patterns, which also led him to connect hominin cognitive evolution to spatial perception and tool-making (Wynn 2002: 431).

These insights on the origin of rock art are now finding support in new neurological discoveries and the emerging hypotheses that integrate the role of mirror neurons in cognitive behaviour. One of these hypotheses, for example, advanced the possibility of an evolutionary link between manual dexterity (grasping) and linguistic skill in communication and proposed that the mirror system for grasping was central to the evolution of an extended mirror system that supports both the use of a tool and the production and recognition of unitary utterances. The plausibility of this hypothesis is supported by the fact that the Broca's area evolved atop the mirror system for grasping, and also the fact that in humans, hand and mouth gestures and the oro-laryngeal movements used for speech production are all neurologically linked (Greenfield 1991; Arbib and Bonaiuto 2008; Arbib et al. 2009a; Arbib 2010, 2011; Rizzolatti et al. 2004; Gallese 2007).

Soon after their discovery in the 1990s, the importance of the mirror neurons and their relevance to the study of palaeoart was recognised and discussed in the works of many rock art researchers, particularly those with long-standing interest in the neuropsychological aspects of this art.

Thus, for example, in Hodgson's work, the integration of the mirror neurons in rock art research was a natural continuation of his investigation of the working of the visual cortex in relation to what he called the 'resonance hypothesis'. This is an exploration of how the visual cortex and the expansion in the human temporal cortex with its function of recognition and visual memory may have been responsible for the development of sensitivity to repetitive patterns that contributed to the rise of rock art (Hodgson 2000, 2003, 2006, 2008). The structure of the visuomotor system, recognition of patterns, repetition and symmetry, he says, gave the brain an empathetic awareness of the constancy and self-sameness that permeate the natural order. Reflecting this brain-structure, the perception of graphic primitives such as cupules, parallels, lines and dots guided the creative action aimed at changing the environment, making tools, producing marks and projecting forms onto surrounding objects. This development constituted a 'transcending of a passive appreciation of symmetry and pattern, towards a more proactive exploitation of such components through actual mark making' (Hodgson 2006: 63).

Hodgson also extends his research on the visual cortex to hyperimagery and hypersound, two phenomena which he and Helvenston connected to the production of rock art and also animism. Different from hallucination, hyperimagery and hypersound are neuropsychological conditions which, under arousal, tend to cause ambiguity and the misconstrual of real objects for subjective images. 'Visual imagination seems to be an aspect of the visual system closely related to visual memory and one that is most "detachable" from everyday reality in that it allows possible scenarios to be played out completely disengaged from the real situation' Hodgson (2008: 342) stated. Brought about by subjective experience (fatigue, fear, sleep deprivation, over-concentration on particular items, anticipation, hunger and stress-related events), hyperimagery creates a bias in the processing of information derived from visual perception of reality and retrieval of visual memories. Contributing to hyperimagery is also the human tendency to perceive movement in inert non-biological objects, which can result in the attribution of cognitive meanings and animacy to objects and animals (Helvenston and Hodgson 2010; also Hodgson 2008: 343). Elsewhere, Helvenston and Hodgson also considered the possibility of rock art emerging in connection with hunting, a human activity in which the use of camouflage and visual deceptions, assisted by the human brain's plasticity, became exaptative projections of supernatural entities (Hodgson and Helvenston 2006). In their neuropsychological studies of animism and the origin of rock art, Hodgson and Helvenston underscored the role of mirroring mechanisms underpinning these cognitive behaviours (Hodgson and Helvenston 2006: 9; Helvenston and Hodgson 2010: 68).

B. Watson connected mirror neurons to the perception of the human form and the graphic representations of the human body that commonly appear in palaeoart. He suggested that the role of the human form in visual perception is particularly salient because of its importance to conspecifics for survival and social interaction. This, he said, resulted in its prioritisation for attention and its prevalence in rock art (Watson 2012). Watson also stressed the phenomenon of movement and its visual-motor process (Watson 2010: 14).

Pointing to the improvements in neural plasticity and the role of mirror neurons for the shaping of the individual's behaviour, Onians thought that mirroring and empathy were important for the development of the visual and motor areas that support art. He also conceived of the possibility that cave art representations may have been prompted by tactile firings triggered by the sight of animal scratches on the cave walls such as at Chauvet (Onians 2007: 309; also Onians 2011).

I will now attempt to survey current research on mirror neurons for the purpose of identifying insights that are relevant to our understanding of the production and appreciation of this art. First, I will briefly review current research on mirror neurons, and then I will examine imitation and empathy, two behavioural phenomena closely linked to mirroring goals and movements attributed to mirror neurons. These two behaviours are also so connected that imitation is thought to be a common condition for empathic responding, if not the developmental origin of empathy (Jones 2009; Iacoboni 2009: 658; Carr et al. 2003).

B. Mirror neurons

Discovered in the early 1990s within the ventral premotor cortex (area F5) and in the parietal cortex (PF) of a macaque monkey, mirror neurons are brain cells that discharge either when a person (or animal) passively observes other individuals (or animals) perform a motor act (goal-related movement such as grasping an object), or when actively executing the same observed goal-oriented act (di Pellegrino et al. 1992; Jeannerod et al. 1995; Gallese and Goldman 1998; Gallese et al. 1996; Gallese 2003; Rizzolatti et al. 1996, 2001; Ferrari et al. 2003). They cause the observed action of a person to be 'reflected' in the motor representation for the same action of the observer, suggesting a shared coding of action perception and action execution — a coincidence of the motor representations of action of the first person ('I') and the third person ('she/he').

In animal tests, mirror activation has been recorded at the single-cell level using depth electrodes, but because it is intrusive, this method is only exceptionally used in human studies. One such a case is in epileptic patients who were already implanted for surgical evaluation, which allowed for the recording of extracellular activity in medial frontal and temporal cortices while the patients executed or observed hand grasping actions and facial emotional expressions (Mukamel et al. 2010; Gelbard-Sagiv 2008). Otherwise, neural behaviour is generally investigated at the system level, the assumption being that brain-cell activity correlates well with in-depth electrodes (Iacoboni 2009: 663). Here, neuroimaging of the automatic activation of motor and premotor areas of the cerebral cortex is achieved using techniques such as electroencephalographic (EEG), magnetoencephalographic (MEG), transcranial magnetic stimulation (TMS, which uses magnetic stimulation to either stimulate or transiently impair a cortical region); and functional magnetic resonance imaging (fMRI). While EEG, MEG and TMS measure electromagnetic behaviour in the brain, fMRI measures hemodynamic changes (blood-oxygenation level dependent or BOLD) (Rizzolatti and Sinigaglia 2010; Keysers et al. 2010).

Although there is a certain homology between the human mirror neuron system and the monkey's, there are certain properties that are lacking or are poorly developed in the monkey. For example, it has been suggested that the human mirror neuron system is activated by the observation of intransitive actions and not only by goal-directed actions as in the monkey (Buccino et al. 2004a: 334; Peeters et al. 2009).

In action observation studies in humans and monkeys, motor neurons are activated even when the final part of an observed goal-oriented action is partially completed or hidden but can be inferred, suggesting that a motor representation can be internally generated despite the absence of a full visual description of the action, and based solely on available contextual information (Umiltà et al. 2001).

In addition to matching action observation and action execution in visual situations, mirror neurons also respond to the sound of actions. Macaques' mirror neurons, for example, can respond to auditory as well as visual cues, such as the sound of tearing a piece of paper to recognise action implied in that sound (Kohler et al. 2002; Gallese 2007: 660; Keysers et al. 2003; Gazzola et al. 2006). Although the ventral premotor cortex contains multimodal neurons integrating auditory and visual information, there is no evidence for a direct anatomical connection between area F5 and auditory cortices (Keysers et al. 2003).

Other than in the premotor cortex and parietal cortex, neuroimaging studies also suggest that there is a shared circuit for actions in the somatosensory cortex, where a matching of the perception and experience of tactile sensations takes place. Using mirror imaging, Keysers et al. showed that observing someone else's legs being touched with a stick activated the secondary somatosensory cortex (SII) and the primary somatosensory cortex (SI, which processes signals that originate in our own body) (Keysers et al. 2004). A study by Blakemore et al. also indicated that neural responses in SI to the observation of touch were somatotopically organised in that different regions responded depending on whether the observed touch is on the neck or on the face (Blakemore et al. 2005). Bufalari et al. also reported different engagements of the somatosensory cortices depending on whether the observed touch is painful or non-painful (Bufalari et al. 2007; also Schaefer et al. 2012; Molenberghs et al. 2012; Keysers et al. 2010; Bastiaansen et al. 2009). As to the rest of the brain, it still remains a *terra incognita* when it comes to mirror neurons (Keysers and Gazzola 2009: 1).

There is a question as to whether or not mirror neurons fire in the presence of non-biological action or when a biological action has no goal (Press et al. 2007; Ferrari et al. 2009, 2012; Buccino and Riggio 2006; Peeters et al. 2009).

Depending on the relation between their visual and motor properties, mirror neurons have been functionally categorised into 'strictly congruent' and 'broadly congruent' neurons (Gallese et al. 1996; Rizzolatti and Craighero 2004; Bonaiuto and Arbib 2009). Studies have shown that while all mirror neurons show congruence between the visual actions they respond to and the motor responses they code, only the 'strictly congruent mirror neurons' match the observed act both in terms of its motor goal (e.g. grasping) and of how it is achieved (i.e. grasping with the whole hand or with a precision grip). The majority of mirror neurons, the 'broadly congruent' ones, instead showed a broader selectivity for the type of grip during action observation when compared with execution (Gallese et al. 1996; Rizzolatti and Craighero 2004).

A subset of mirroring cells is also thought to exhibit inhibitory property, a neural feature that may help preserve the sense of selfhood of the owner of an action during execution, and exert control on unwanted imitation during observation (Mukamel et al. 2010). Activation of mesial areas is also thought to play a role in the control of action execution, particularly the necessity to inhibit the selected action until its execution is allowed (Buccino et al. 2004a; Ferrari et al. 2009; Brass et al. 2009). According to Rizzolatti and Sinigaglia it is a possible 'that one can inhibit a natural (mirror) response and voluntarily organize a different response', according to the particular situation (Rizzolatti and Sinigaglia 2010: 270).

Upon their discovery, mirror neurons stirred a great excitement, and were enthusiastically embraced as providing the basis of action understanding (see Rizzolatti et al. 2001; Rizzolatti and Craighero 2004: 172). It was thought that by providing a direct matching of observation and action, mirror neurons allow the observer to figure out the outcome, and ultimately the goal, of the action based on prior experience (Gallese et al. 2004: 396). According to Rizzolatti et al., 'an action is understood when its observation causes the motor system of the observer to "resonate" ' (Rizzolatti et al. 2001: 661).

In addition to facilitating understanding through motor simulation, mirror neurons have also been implicated in other cognitive functions, including imitation (Iacoboni et al. 2005; Brass and Heyes 2005; Buccino et al. 2004a; Rizzolatti et al. 2001; Wohlschläger et al. 2002), empathy (Carr et al. 2003; Gazzola et al. 2006; Damasio and Meyer 2008; Blakemore et al. 2005; Iacoboni 2009; Zeki 2009; Zaki 2012), dance therapy (Homann 2010), calligraphy (Longcamp et al. 2006; Knoblich et al. 2002), literary analysis (Rokotniz 2008), acting (Blair 2009) and video games (Collins 2011) — and many more.

The initial interpretation of the function of the mirror neurons as a basis of understanding (motor-based action understanding), however, did not go unchallenged, as criticism arose prompted by an array of contrary evidence. For example, the observation of a particular hand gesture can cause motor neurons to fire, but because such a gesture can have more than one meaning, contextual conditions become a factor in determining the intent, which implies a complex inferential process. Yet some of the brain areas responsible for the inferential processes in novel situations lack mirror properties, leading to the conclusion that action understanding is primarily mediated by an inferential interpretive system rather than the mirror system (Brass et al. 2007; Lingnau et al. 2009). It was also found that, while sensory and/or motor impairments do not necessarily give rise to conceptual deficits, motor responses are defective when some parts of the brain other than mirror neurons are afflicted with lesions. For example, lesions in the frontal lobe are often associated with motor deficits. Similarly, lesions in the medial temporal lobe are also associated with perceptual deficits. It seems that perception and action, which are united at the level of single cells, are more easily separated at the system level (Mukamel et al. 2010).

There are even some who doubt the existence of mirror neurons (Lingnau et al. 2009; Hickok 2009; Turella et al. 2009; Negri et al. 2007). In fact, some think that the mirroring system is nothing but Pavlovian association involving stimulus-response action, and reject the idea that 'understanding' is a sensory and motor simulation; rather, they maintain, concepts formation (symbols and abstracts) is the product of a disembodied cognitive function (Dinstein et al. 2008; Mahon and Caramazza 2008: 59; Heyes 2010; Catmur 2009). Generally, the view among doubters is that the activation of motor information is not necessary in order to successfully recognise and understand actions and objects (Negri et al. 2007: 797). Rather, they believe 'that activation in mirror neuron areas reflects the facilitation of motor programs as a consequence of action understanding' (Lingnau et al. 2009: 9928).

And there are those who minimise the role of mirror neurons. For example, Churchland (2011: 140) thinks that mirroring is capable of explaining only movement and basic action, while understanding complex actions is a higher-level process.

Finally, it is perhaps of interest to mention some of the views relating to the phylogenetic and ontogenetic significance of the mirror system. Ontogenetically, the importance of mirror neurons is, as we will see, manifested in their role in learning through exposure, imitation and self-discovery. Phylogenetically, some think that the mirror neuron system might have evolved in primates to facilitate matching action and motor representations and to provide feedback for visually directed grasping. The mirroring system was subsequently 'exapted', through a generalisation process, to interpret the goal-directed behaviours of others for social interaction and communication purposes (Casile et al. 2011). Others think that mirror neurons acquire their matching properties during ontogeny, through the correlated experience of observing and performing actions. That is, mirror neurons are a product of sensorimotor experience, and not an innate endowment (Cook 2012; Del Giudice et al. 2009).

1. Mirror neurons, imitation and rock art

1.1 Mirror neurons and imitation

Imitation is the ability of individuals to learn to do an action from seeing (or hearing) it done (Byrne and Russon 1998, citing Thorndike). A behaviour that begins with observation, imitation is the translation of sensory information into motor commands in such a way that the actions of the observer match the actions observed (Wohlschläger et al. 2003). A key for the acquisition of behavioural strategies, imitation requires a great deal of perception-motor coordination. Sometimes, imitation itself may require the acquisition of a novel motor pattern or a novel recombination of old ones (Byrne and Russon 1998; Byrne 2003; Buccino et al. 2004a).

Simulation is often used interchangeably with imitation (see e.g. Iacoboni 2009), and, in fact, mirroring is thought of as an internal simulation of what we see or hear (Gallese 2003; Negri et al. 2007: 797; Mahon and Caramazza 2008). Imitation, however, is distinguished from emulation. Emulation is task-oriented, its goal being the reproduction of the outcome of an observed action by the observer's own means rather than re-enactment of the motor pattern of the action under observation (Ferrari et al. 2012; Csiba 2007: 438; Tennie et al. 2006; Byrne 2003).

There is a question as to whether the ability to imitate is learned or innate. Based on the fact that, without visual access to their facial features, neonates are capable of performing some facial imitations, it has been suggested that the matching of others' visible movements with one's own movements is an inborn ability. Indeed, infants do respond to some adults' facial movements, such as opening the mouth, pouting and tongue protrusion (Meltzoff and Moore 2002, 2005, 2007; Byrne and Russon 1998; Fadiga et al. 2000; Wohlschläger et al. 2003; Oztop et al. 2004; Casile et al. 2011; Ferrari et al. 2006, 2009, 2012). There are, however, some doubts as to the possibility of neonate imitation. S. Jones, for example, 'proposed that the only reliable behavioural matching found in newborn infants — the matching of tongue protrusions — is not evidence of their ability to imitate, but is instead the coincidental matching of a sight that infants find arousing with a behaviour that infants characteristically produce when aroused' (Jones 2009: 396; Catmur 2009).

In any case, infant facial imitation, which tends to decrease and disappear over the first six months, clearly has a social function, furthering group bonding.

Another imitative behaviour that appears early in infancy, and which involves learning and response facilitation, is grasping (Ferrari et al. 2012; Oztop et al. 2004, 2006; Fadiga et al. 2000; Byrne and Russon 1998; Byrne 2003; Arbib and Bonaiuto 2008).

The fact that imitation has been associated with both social bonding and skill learning has led to speculation that imitative behaviour may have evolved twice in the human lineage, perhaps under different selective pressures: a relatively low-level imitation with a social function, and relatively high-level copying with a skill-acquisition function (Byrne and Russon 1998: 715).

The mechanisms which underpin imitative behaviour are not fully understood, but neuroimaging studies have identified various brain areas involved in imitation, including the inferior frontal gyrus, the dorsal and the ventral premotor cortex, the inferior parietal cortex, the superior parietal lobule and the posterior superior temporal sulcus (Fogassi et al. 2005; Brass and Heyes 2005; Buccino et al. 2004a). It is also thought that the functional significance of the mirror mechanism may vary depending on the location of mirror neurons in different brain areas. For example, the mirror mechanism in the parietofrontal circuit may be relevant to understanding the goal of observed motor acts and the intentions they imply, whereas the mirror mechanism in the insula might underlie the capacity to understand a specific emotion of others, such as disgust (Mukamel et al. 2011: 754; Keysers and Gazzola 2006).

As to how they effectuate imitation, the mirror neurons are thought to respond to observed motor acts (e.g. finger lifting, precision grip) by encoding them into elementary components which are subsequently recombined into a new action matching the observed one not only in terms of action goal, but also of specific motor patterns. When imitation involves a novel motor pattern or a novel motor sequence, a further mechanism is required, consisting of a recombination of the 'resonated' motor acts into a new motor pattern or a new motor sequence (Buccino et al. 2004a; Rizzolatti and Craighero 2004; Voelkl and Huber 2007; Ferrari et al. 2009). A possible mechanism for this process is thought to include three main steps: (1) a visual description of the observed movements involving the occipito-temporal cortex; (2) sending this visual description of the observed motor acts to the parietal cortex, where it is categorised and transformed into potential, goal-directed motor acts; (3) the goal-related information reaches the premotor cortex, where motor acts and their visual counterparts are clustered largely according to a somatotopic coordinate system (Mukamel et al 2010; Jastorff et al. 2010).

While the information flow within the mirroring system seems to be predominantly from premotor to parietal and middle temporal cortices, the flow of information between the mirror neuron system and the brain is dynamic and subject to feedback. During action observation, the parieto-frontal circuit receives high-order visual information from areas located inside the superior temporal sulcus (STS) and the inferior temporal lobe (IT), neither of which has motor properties. During voluntary movement, the input to the parieto-frontal circuit is mostly from the frontal lobes. These areas of the human brain, normally associated with planning, preparation, execution and proprioception of our own actions, were found to be also involved in the hearing or observation of actions (Keysers 2003; Keysers and Gazzola 2006; Keysers et al. 2010; Schippers and Keysers 2011; Rizzolatti and Sinigaglia 2010).

1.2 Imitation and rock art

In order to integrate what has been said about the functional role of the mirror neurons system into our understanding of palaeoart, it is necessary to devise a working definition of palaeoart. For simplicity, this definition is focussed on drawing — a main activity in rock art.

Drawing is a visuomotor control in which visual features and movements registered in the parietal cortex (or retrieved from memory) selectively activate motor and premotor areas that are part of the mirror-neuron system matching action observation and execution so that, with input from other brain areas, these visual features and movements are translated into a graphic representation on a two-dimensional surface. In palaeoart, this visuomotor process results in a representation of an object or symbol on the face of a rock, a cave wall, a bone, an antler, eggshell, ivory or a plaquette.

Aside from its reference to mirror neurons, this definition of drawing is common among artists. Alexander Calder (1896–1976), for example, described artistic production as follows:

> First, the eye and the brain, or the brain alone, must act and determine what is desired to place on canvas or paper. This is a mental process. The second process is physical, for the hand must so control the pencil or brush that the desired effect may be obtained, that the image the eye has carried to the brain may be correctly transmitted to canvas or paper (Calder 1973: 62; also Turner 2006: 79–80).

As indicated, drawing in rock art often consists of producing a graphic likeness of an animal or human, but such a representation is not imitation. The correspondence between the animal and its picture is not as in the mirroring mechanisms, action-as-seen to action-as-done; it is rather a graphic parallel to it, involving distal manual manipulation and a matching of action that is visual and outside the body.

Yet drawing and imitation are not without significant similarities in their sensorimotor mechanisms (when the target or object is a biological agent — the motor responsiveness to mechanical objects is still being studied, see e.g. Urgesi et al. 2006; Ferrari et al. 2009). For example, both drawing and imitation rely on the perception of the organisational structure of observed behaviour of the target agent or object. They both use similar mechanisms for recognising, tracking and mapping the observed movement onto one's own motor apparatus for the purpose of reproducing it. They also involve the ability to abstract from observation not only the goal of an action but also a visual representation of possible trajectories that achieve it; often with feedback corrections (see Arbib 2011: 268). But whereas imitation reproduces the observed acts faithfully, even with some mutuality and reciprocity (Meltzoff and Moore 2002: 39), drawing translates them into graphic likeness. Here we are presented with a unique paradox: whereas imitation reproduces movement, rock art representation freezes it.

The gap between imitation and drawing is even narrower when we consider self-imitation, which is of interest to a wide range of human activities, including rock art. Indeed, self-imitation is crucial for the development of perceptual (motor and visual) aptitudes. It also provides needed reorganisation of motor programs in the face of disruption (Arbib et al. 2009; Bonaiuto and Arbib 2010). Infant behaviour, for example, displays a variety of self-imitative acts in which infants are able to repeat actions they have just performed. In self-imitation, the observable action usually consists of visual, proprioceptive and auditory cues (Gardner and Heyes 1998: 691; Saunders et al. 2006; Bonaiuto and Arbib 2010).

Just as in imitation, mirror neurons are thought to be active in self-imitation, helping monitor one's own actions so as to learn how to deploy motor skills efficiently. Both imitation and self-imitation help in priming neural correlates of action patterns in a given repertoire, resulting in greater response facilitation (Byrne 2003).

It is easy to see, from what has been said, how imitation is important to rock art. As a repetitive behaviour, imitation helps the developing rock artist create 'internal models' that are used for novel action and for increasing the speed and accuracy of the movements needed for the production of a drawing. Both imitation and self-imitation impart the skills needed for mapping the visual variables of the subject to be drawn into corresponding movements, and maintaining equivalence between the object and its depiction. At the early stages of learning rock art, the equivalence between the drawn outline of an animal and the animal it represents provides a basis for reinforcement learning and monitoring one's own action, a process not unlike the reinforcement signal assumed to stabilise and guide the infant action of reaching and grasping, or what Arbib et al. (2009: 451) call *joy of grasping*.

The above definition of drawing assumes the presence of the object in front of the artist. However, it is often the case in rock art and cave art that the image is formed internally from the artist's memory (Onians 2011). Though this internal representation is abstract and effector-independent (see Arbib et al. 2009: 443), it provides a schema generating movement and also feedback for planning the trajectory of that movement so that the lines and stroke produced combine to form at least a minimally recognisable likeness of the imagined figure. This ability to organise one's motor programs in response to the kinematics of the figure being drawn includes anticipation of different curves and strokes and the maintenance of their proportionality as well as the correspondence between the final representation and its referent object.

As a distal manipulation and a matching of action that is visual and outside the body, drawing involves adjusting the motor programs of the body according to the intended image and the selected end-effector. That is, different body movements are required depending on whether the figure is produced using pecking and incision, ochre pencil or mouth-spray; and also whether the figure is small or monumental, or on a horizontal surface or a vertical one. For example, studies have shown that goal-directed movements such as dragging, dropping, grasping and pushing are coded according to the effectors performing them (foot, hand and mouth), and also according to the direction of the movement (e.g. towards or away from the agent) (Jastorff et al. 2010: 128).

In this respect, the sensorimotor mechanisms involved in rock art production are not unlike those implicated in handwriting, another graphic activity that is primarily manual and with a significant component of self-imitation. Just as in rock art, the letter in writing often starts as an internally generated image, and writing action uses feedback to plan the movement of the efferent tool (pen, brush etc.) and to maintain equivalence and proportionality in the letter-shape. This remains true whether it is a small script produced using the fingers, or a large one involving the use of the arm, or an extended pencil or brush. In each case, the kinematic regularities and details of movement remain the same. Even personal style as reflected in letter forms remains constant (Wing 2000; Arbib et al. 2009; also Longcamp et al. 2006; Knoblich et al. 2002; Freyd 1983; Hardwick and Edwards 2012; Schaefer 2012).

2. Mirror neurons, empathy and rock art

2.1 Empathy and art

Although empathy is thought of as a higher-order cognitive process that is distinguishable from motor activation, empathic understanding still includes an important motor component. For example, functional imaging studies have shown that the observation of another person displaying facial expressions, experiencing an emotion (pain, disgust), or being touched activates the same limbic and sensorimotor systems that are active when the observer him/herself experiences similar states or perform similar actions (Carr et al. 2003). Different aspects of empathy may also be associated with different neural substrates. Fear, for example, is associated with the amygdala and disgust with the insula (Carr et al. 2003; Gallese 2003; Blakemore et al. 2005, 2006; Banissy and Ward 2007; Bufalari et al. 2007; Damasio and Meyer 2008; Bastiaansen et al. 2009; Iacoboni 2009; Zeki 2011).

In art, empathy is perhaps what most defines the relationship between an artist and his/her work. This empathic relationship is well articulated by J. Croney (1983: 22):

> It is certain that the more concrete a subject becomes in terms of our sensations, the more we have empathy for it and identify with it, and it is in this way that a drawing comes to life. At some stage of the figure drawing we may even 'act out' in our imagination the figure's position and its meaning, and believe in its reality. The drawn image can have no real existence unless our own bodily attitudes have been involved in its making. When a drawing is really creative the draughtsman fulfils his own sensations, going over the subject repeatedly in his mind so that all its perceptible movements have found sympathy with his own habits of action.

Although the implications of the discovery of mirror neurons for aesthetics are not fully known, some progress is being made in the study of the neural processes that arise in empathetic phenomena connected with visual arts. For example, functional studies of the mirror system have shown that in painting, drawing and sculpture, the artist's hand leaves invisible but detectable traces which are directly accessible to the observer even a long time after the action has taken place. These traces include line patterns, strokes, brushworks and vigorous application of the hand in modelling or shaping the medium. This readability of movement is due to the fact that the visual perception of hand-made traces relies on mechanisms similar to those described for action observation (Freedberg and Gallese 2006: 197).

An example of the readability of the traces of the artist's body in his/her artwork and the empathetic response of observers to it is provided in a study conducted by Freedberg and Gallese. Focusing on the role of the mirroring mechanisms in visual art, they tried to identify the 'felt effect' of the creative gestures that went into producing a number of artworks as reported by viewers during their contemplation of these artworks. They found that looking at the image of a finger probing a bodily wound, as in Caravaggio's *Incredulity of St Thomas* (1601–1602), or the infliction of bodily injury, as in Goya's *Desastres de la Guerra,* induced empathy for tactile sensations resulting from the automatic activation of part of the same network of brain centres that are normally activated by our own sensation of pain. Viewing Michelangelo's sculptures *The Prisoners* was also found to elicit an embodied simulation, 'a felt activation of the muscles that appear to be activated within the sculpture itself, as if in perfect consonance with Michelangelo's intention of showing his figures struggle to free themselves from their material matrix' (Freedberg and Gallese 2006: 197). Even in abstract paintings such as those by Jackson Pollock, viewers were apt 'to experience a sense of bodily involvement with the movements that are implied by the physical traces — in brush marks or paint drippings — of the creative actions of the producer of the work'. And the slashed painting of Lucio Fontana caused a sense of empathetic movement resonant with the gesture that produced the slashing. Freedberg and Gallese concluded that, in the presence of an artistic representation, beholders generally tend to automatically simulate the emotional expression, the movement or even the implied movement within the representation (Freedberg and Gallese 2007; Casati and Caggian 2007).

2.2 Embodiment

This physical involvement which the viewer may experience while viewing a painting or a sculpture and which the artist may also experience during the creative process is referred to as embodiment. In Arbib's words, embodiment 'refers to the idea that the representational content of motor acts and perceptual processes has a sensorimotor (not conceptual) grounding which is intimately related to (and used for) the actions available to the embodied observer' (Arbib 2010: 16; also Gallese 2007: 660; Maiese 2011). In its core, embodiment is thought of as a functional mechanism through which observed actions, emotions or sensations activate our own internal representations of the body states that are associated with social stimuli, as if we were engaged in similar actions or experiencing similar emotions or sensations (Gallese and Freedberg 2007: 198).

Yet even before its neurophysiological definition, artists and art theoreticians were aware of the cognitive significance of embodiment. Thus, for example, long ago, Berenson pointed out that paintings and drawings are not only visual impressions, but also bear the tactile and haptic marks of the artist's aesthetic experience (Berenson 1948; also Turner 2006: 79–80; Achrati 2008).

According to the embodied cognitive approach, rather than being a conceptual association of vision, drawing is a somatic experience where spatial perception is seen as a multi-sensory process. Shapes and spatial features are perceived by touch and haptic perception (the exploration of movement), as well as hearing, which is an important source of distal stimuli (Millar 2006; Hopkins 2000, 2004; Kennedy 1982; Kennedy et al. 1991; Kennedy and Juricevic 2006; Cain 2010; Achrati 2007, 2008, 2010). From an embodied point of view, spatial coding consists 'of integrating inputs from diverse sources as potential reference cues that specify the location ("where?"), distance ("how?") or direction ("what turning?") in perception and action that a task demands' (Millar 2008: 2).

3. *Empathy with non-conspecific*

Given that the corpus of rock art consists mainly of animal representations, any discussion of empathy in rock art as proposed in this article has to address three critical questions:

a. Is empathy with non-conspecifics possible?
b. How is empathy manifested in rock art?
c. What are the mirroring mechanisms that underpin this artistic empathy?

Empathy usually refers to intersubjective behaviour involving affective response to another person's emotional experience, but human empathy also extends to animals (see e.g. de Waal 2007, 2009; Edgar et al. 2012; Parviainen 2003; Thorndike 1898). As indicated by Calder, people in general and artists in particular do show an understanding of the animals they come into contact with and empathise with them. 'Animals', wrote Calder in *Animal sketching*, 'think with their bodies to a greater extent than man does. In anger or flight, ears flatten against the head, the hair along the spine rises. The dog at the sight of food drools at the mouth, male birds courting display their feathers … There is no self-consciousness: animals are always intent upon the thing they are doing, and we must feel that they are as we sketch them' (Calder 1973: 62; Turner 2006: 80–81; see also Brener 2005: 23–24). Pre-Historic rock artists, then, must have been at least capable of the same empathic disposition towards the animals they drew or painted as their modern counterparts do.

Indeed, pre-Historic artists related to animals on many levels. They shared the wilderness with them and hunted them during the day; at night, they participated in the clan's mimetic vocalisation, facial expressions and body movements of these animals either as prey or idealised beings (Bednarik 2003: 127; Hodgson and Helvenston 2006: 11). And when the mood struck, they painted and engraved images of their favoured animals on flat surfaces.

The question to be discussed now concerns the neural mechanisms by which a rock artist's empathetic understanding of non-conspecifics is processed.

A clue to the answer to this question is in a study by Buccino et al. (2004b).To find out whether the observation of actions made by non-conspecifics would activate the same cortical areas in humans that are active during the observation of the same action by another human, Buccino et al. used fMRI to examine subjects viewing silent video scenes in which a human, a monkey, or a dog performed ingestive (biting) or oral/communicative (talking, lip smacking, barking) acts. They found that while volunteers recognised all the observed motor acts, there was activation of parieto-frontal mirror areas only in two cases: in human speech and in biting regardless whether the agent was a human, a monkey or a dog. For barking, they found no motor activation, while for monkey lip smacking, they recorded only a weak activation. The activation that occurred during the observation of barking was in the occipital visual and superior temporal sulcus areas, with no frontal lobe activation (Buccino et al. 2004b).

These results suggest that emotion identification depends on a cortical mirror system that enables the embodiment of observed motor behaviour within one's own motor system, with inputs from other parts of the brain (for the neural structures of emotions, see Nolte 2002: 578–580). They also demonstrate that humans can recognise animal actions that are in the human motor repertoire. Those actions that are beyond motor generalisation are recognisable through the integration of other brain mechanisms, such as the occipital visual and superior temporal sulcus areas (Buccino et al. 2004a; Rizzolatti and Craighero 2004; Rizzolatti and Sinigaglia 2010; Spunt and Lieberman 2012).

These findings are also consistent with single-cell recordings and neuroimaging in humans and animals showing that the superior temporal sulcus (STS) region is important in processing sensorimotor perceptions of facial expressions and body movements (Allison et al. 2000; also Puce et al. 2003). Recorded responses included facial features such as the forehead, the eyebrows, the eyelids, and the direction of the gaze, which are important cues conveying intimacy and intentions.

In monkeys, for instance, open mouth and bare teeth can signal threat or fear, while teeth chattering and a fear grin indicate submission. Head movements and inflections also convey emotional information. The movement of each of these facial and body parts was found to elicit a preferential responsiveness of STS cells (Allison et al. 2000).

In summary, observing the actions and emotions of other people activates premotor, posterior parietal and somatosensory regions in the brain of the observer which are also active when performing similar movements and experiencing similar feelings. This embodied simulation which is often associated with empathy also obtains when humans observe other animals, or non-conspecifics, to the extent that the observed behaviour is within the human motor repertoire.

In the following, I will now examine the form and content of different rock art images to find out how empathic perception of animals has affected the representational techniques of a range of wild fauna. This requires a brief review of the various representations techniques in rock art.

4. Animal empathy in rock art

It is difficult to know whether all rock art representations are empathetic. Perhaps the only way to generalise empathy to all forms or rock art is to recognise the fact that art includes an element of play and playfulness that provides some pleasure. Indeed, as J. Sully has indicated, drawing and playing are nothing but a 'bodying forth of a mental image onto the semblance of outward life' (Sully 1977: 322). Acknowledging this idea, Huizinga went as far as to describe man as *Homo ludens* (Huizinga 1956; also Spears 1996; Guthrie 2005). In fact, to recognise the ludic nature of art is merely to accept a fact that the origin of artistic behaviour is in biology and the uniquely human disposition for pleasure and revulsion of *ennui.*

Even barring the ludic hypothesis, it is still reasonable to assume that most pictographs and pictograms express a measure of empathy. Aside from the drive, energy and time they consumed, an indication of the empathic character of rock art representations may be the privileging of animals that are dangerous and of no significant contribution to human diet, as archaeologically documented (Camps 1993; Azéma 2010).

Artistic drawings and representations come in many projectional forms: topological, orthogonal, vertical, oblique, naive perspective, and perspective (Willats 2005: 6). These projectional systems involve various cognitive and perceptual processes, including control of movement of the hand, memory, intelligence, attention to details and the position of the parts, their composition, and their relationship to the whole, temperament and mood (Jolley 2010: 11–12).

Depending on the degree of likeness to the represented object, some scholars distinguish between intellectual and visual realism. Intellectual realism involves drawing what one knows and produces a representation in which all (or most) of the constituent elements of the object are individually shown in their entire shape, using transparency, separation, plan and folding-out (ibid.: 13). Visual realism involves a shift to perspective using occlusion, diminution, overlapping and foreshortening (ibid.: 17).

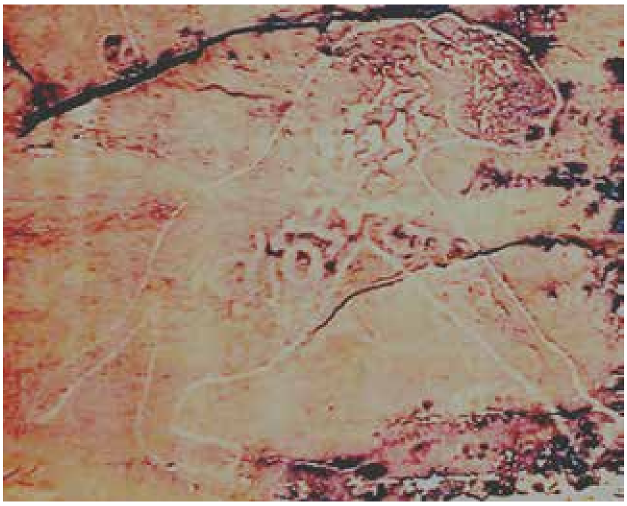

Figure 1. *'Leopard', Sfeisifa, Algeria. Photo A. Achrati.*

Though skill is important, our preference for either realistic or naive, stylised representations is a matter of cultural and aesthetic orientation. At the beginning of the twentieth century, for example, the avant-garde artists sought liberation from the figurative in abstraction and believed that the simplicity of stylised, child-like drawings was more expressive (see e.g. Klee 1995; for historic changes in the definition and function of drawing, see Petherbridge 2008).

4.1 Profile or lateral view

In rock art engravings or other petroglyphs, individual animal figures are usually drawn in profile, with the characteristic features of the animals well depicted, as in the 'leopard' from Sfeisifa, Algeria (Fig.1). Sometimes, this lateral depiction is combined with some distinctive features of the animal, such as horns and/or eyes, which are presented as if seen from the front (Fig. 2). This 'twisted perspective' is used for the purpose of identification of the animal, but it can also indicate a lack of skill. With emphasis on the cervico-dorsal line and the salient features of the animal, these lateral depictions come in varying degrees of realism, ranging from the elementary and schematic to the highly realistic. They are also ancient and widespread, occurring among the Upper Palaeolithic cave paintings of Europe and in the Holocene rock art of the Sahara, southern Africa, Arabian Peninsula, Baja California and the Gwion figures, north-western Australia.

In animal paintings, a naturalistic figure in lateral view is sometimes given depth using shading and polychromic colours to articulate the anatomy of the animal. The painted horses at Lascaux, France, and

Figure 2. *Bubalus in a twisted view, Sfeisifa, Algeria. Photo A. Achrati.*

the elands of Drakensberg, South Africa, are good examples of this superb naturalism. Sometimes, the bulging feature of the supporting rock is incorporated in this representation technique, as in Altamira.

When a rock art scene includes more than one animal in profile, depth and perspective can still be achieved using proportionality, or occlusion, or both. The mere proportions of the lateral animal figures in relation to each other can give the pictorial narrative a perceptible sense of depth, as in the 'swimming deer' at Lascaux, where the differences in the size of the figures induce an impression of distance and nearness (Fig. 3). In addition to depth, the combination of perfect profile and proportionality can also produce moving pictorial narratives, such as the 'mother elephant' protecting her 'cub' from a 'leopard' in front (Fig. 4).

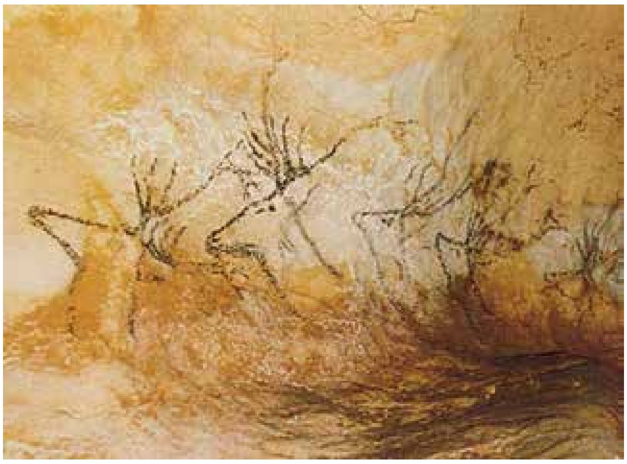

Figure 3. *'Swimming deer'. Lascaux. Photo P. Bahn and J. Vertut.*

Even more complex and highly expressive narratives can be achieved in this way, as, for example, in the panels of Chauvet, which wonderfully capture the moods of the animals (Azéma 2010; Clottes 2003; White 2003), or the Iheren frescoes in the Tassili, Algeria (Hachid 1998: Figs 393–395; Lajoux 2012: 113–119; Kuper 1978: 424–425). When a fanning effect is added, as in the rhinoceros of Chauvet and the ostriches of the Sahara, it creates a sense of movement, vigour and grace (for a creative animation of laterally represented animals, see M. Azéma at *http://www.youtube.com/watch?v=x8exsw6yKXwandfeature=player_embeddedandnoredirect=1*.

Few hypotheses have been proposed for the predominance of the profile technique in rock art. One view attributes the predilection for lateral representations to the fact that the profile of a running animal provides hunters with greater affordability in terms of viewing and targeting (reviewer's comment). The twisted perspective, on the other hand, has been explained as a reflection of the artist's heightened awareness of the animal's horns, hooves, antlers or tusks, which can potentially cause injury or death (Hodgson 2008: 348).

Figure 4. *'Mother elephant protecting her cub', Sfeisifa, Algeria. Photo A. Achrati.*

4.2 Dorsal and ventral views

Dorsal views (view from above), and ventral views (view from below) are exceptional, but they have been recorded in rock art. An astonishing example of dorsal views from Drakensberg, South Africa, has been reproduced by P. Vinnicombe (Fig. 5) and is in the frontispiece of her book (Vinnicombe 1976; two other dorsal views are in her Figs 105 and 165). Two other interesting dorsal views are also from South Africa, showing a 'doe' and 'fawn' lying down with their backs to the viewer (Battiss 1948: 138). The 'sleeping gazelle' of Tin Taghert, in the Tassili, Algeria, may also be included in the dorsal, or view from above, category, considering the way the face rests on an extened front leg in this petroglyph (Fig. 6).

What is intriging, though, is that the dorsal view of the 'elands' from Drakensberg, as can be seen in Figure 5, are found in panels that assemble other 'elands' in all sorts of positions (frontal, lateral and rear). This pastiche may indicate that true prespective did not mean much to the palaeoartist even when in possession of full mastery of the technique, and that perspectival representation is a cultural orientation, as previously indicated.

As to the ventral view, a painting at Reedy Creek, Watarrka National Park, Australia, reproduced in Flood (1997: 174) shows an 'emu's nest with eggs' between the legs of the bird, as well as the bird's beak and tail, all as if seen from beneath through a glass floor, or in snapshot-like image of the nest during the absence of the adult or after it had been abandoned (Fig. 7).

Their artistic achievement notwithstanding, perhaps these dorsal and ventral depictions ought to be counted among the uncommon creative occurrences in rock art which include the suggestive marks that are sometimes added to a particular feature in the rock so as to bring forth its accidental zoomorphic or anthropomorphous appearance (e.g. 'human face' at Fontanet).

4.3 Frontal and rear views

And then there are those representations where the individual animal is captured in full frontal view. One of the most impressive frontal images is that of a charging elephant (Fig. 8) from Mathendous, Libya, first reported by L. Frobenius and reproduced in K. H. Striedter (1986: Fig. 5, p. 72) and in Castiglioni and Negro (1986: Figs 251, 252). Other spectacular frontal views of animals are found among the painted elands of South Africa, examples of which are in the above-mentioned frontispiece.

***Figure 5.** 'Eland' viewed from above. Reproduction of P. Vinnicombe. Courtesy The Rock Art Research Institute, South Africa.*

***Figure 6.** 'Sleeping gazelle', Tin Taghert, Tassili, Algeria. Photo M. Hachid.*

***Fig. 7.** 'Emu's nest'.*

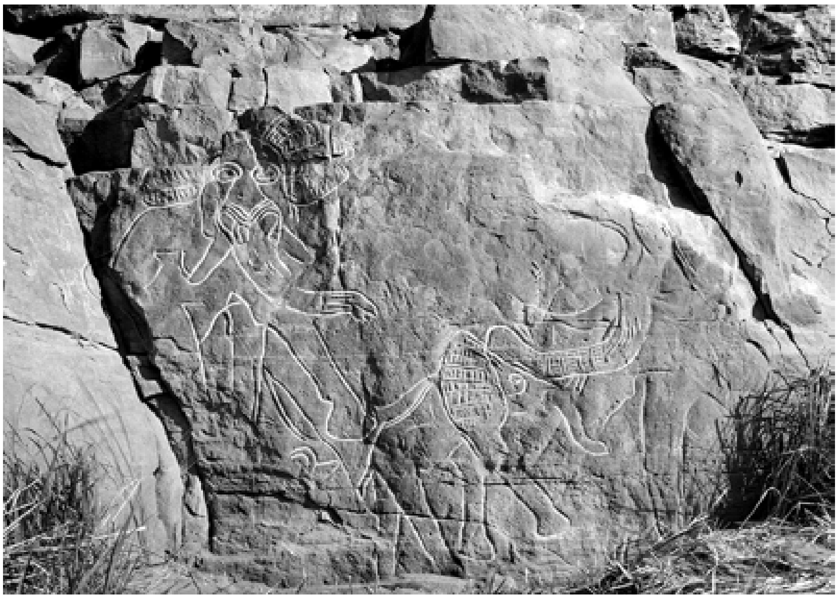

***Figure 8.** 'Charging elephant', In-Habeter, Libya. © Frobenius-Institut, Franfurt am Main.*

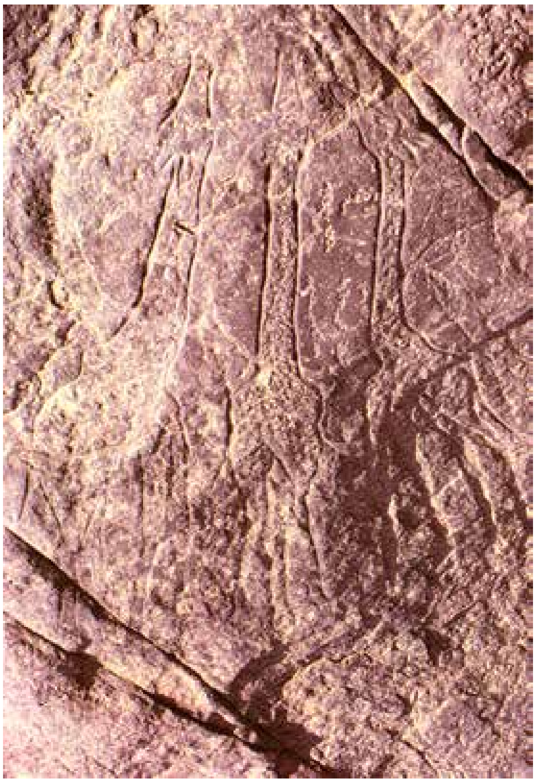

Figure 9. *Three 'giraffes' eating imaginary tree leaves. Photo M. Hachid.*

Figure 10. *'Eland' viewed from behind. Christmas Shelter documentary painting by S. T. Bassett; all rights reserved. (S. T. Basset does his reproduction of rock art using pre-Historic tools, pigments, binding agents; see Bassett 2001).*

Equally impressive are the images of animals viewed from the rear, as in the middle 'giraffe' from Tin Teghert, in the Tassili, Algeria (Fig. 9), or the 'elands' from South Africa (Figs 10 and 11). These frontal and rear views of animals are extremely rare in the rock art record. Most of the rear views of animals come from South Africa, nine of which are reproduced in Battiss (1948: 210–211).

Less rare are the near- or partially-frontal images showing the animal engaged in some biological activity, such as the giraffe and the calf, each scratching its head with its hind leg (Fig. 12), or the 'bull' licking its hind leg, perhaps to remove an itch or mend a cut (Figs 13 and 14), or the 'antelope cleaning its newborn' (Fig. 15).

Included in these intermediate poses be-

Figure 11. *'Eland' viewed from behind with head turned to the side. Reproduction of P. Vinnicombe. Courtesy The Rock Art Research Institute, South Africa.*

Figure 12. *A 'giraffe scratching its face'. Courtesy J. W. Hansen (2009: 40).*

Figure 14. *A 'bull licking its hind leg'. Courtesy C. Dupuy and D. Bernard.*

Figure 13. *A 'bull licking its hind leg'. Photo M. Hachid.*

Figure 15. *'Antelope cleaning its newborn'. Iheren, Tassili, Algeria. Courtesy J.-D. Lajoux.*

tween the frontal view and the lateral view are also images of animals standing or lying down, with their turned heads placed in the foreground as in the 'antelope' (Fig. 15), or the 'cow giving birth' in Fig. 16. In these intermediate poses, the head sometimes occludes parts of the body, and sometimes the body occludes the head. In a painting of an eland in the Drakensberg, for example, the animal's head is on the hidden side of the body with only the muzzle visible below its abdomen (Lewis-Williams 2003: Fig. 33; also Battiss 1948: 143, 151). Occasionally, instead of the animal's head being turned to the back (Fig 17), the animal's full face and gaze are fixed on the beholder, as in the 'lions' from Les Trois Frères (in Bégouën and Breuil 1958: Fig. 3, p. 11), or the bas-relief of a cub from Alamasse, Libya (Lutz and Lutz 1995: 82, Fig. 109).

All these frontal, rear and partially frontal figures show a sophisticated degree of foreshortening. What is amazing about these representations, aside from their stunning realism, is the remarkable pathos they exude. They also happen to be extremely rare in the rupestrial record. The scarcity of these images is obviously due in part to the difficulty of the artistic skills required for the execution of such images. But that is not a sufficient explanation because these images are rare even in areas where pictorial naturalism is abundant, as in the cave art of Europe, or among the so-called monumental period imagery of the Sahara, or in the Drakensberg, South Africa.

The explanation for both the artistic accomplishment of these frontal/near-frontal/rear images and their rarity, this article suggests, may be to their highly empathetic character and the action of the mirror neurons that attended their production.

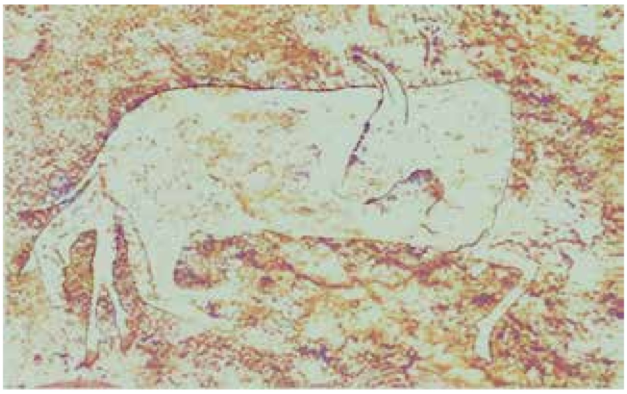

Figure 16. *A 'cow giving birth', Iheren, Tassili, Algeria. Courtesy J.-D. Lajoux.*

Figure 17. *'Eland' turning its head to the back. Christmas Shelter documentary painting by S. T. Bassett; all rights reserved.*

4.4 Rock art pathos

Although there has been no survey of the range of emotions apparently expressed in rock art, this art is replete with explicitly moving expressions. To name only few, there are animals with teary eyes (Achrati and Bokreta 2005); animals giving birth (Muzzolini 1995: Fig. 321; van Albada and van Albada 2000: Fig. 63; Lajoux 2012: 177), or showing maternal care (Lajoux 2012: 115), animals in distress, animals in rut (van Albada and van Albada 2000: 34), animals in flight, resting animals, excited animals, and animals stalking other animals. Most often, what makes these empathic states accessible to us is the realism or near-realism of the figures and also their compositional relationship which creates a context and a discernible pictorial narrative, as in Figure 4. But not all empathic gestures in rock art are easily readable, especially when the animal figure is isolated.

One way of assessing and categorising empathic expressions in individual rock art figures or in complex scenes is to focus on the 'felt effect' of the creative gestures and their mirror neuron correlates. And this is when depth and perspective come into play.

5.5 Kinaesthetic (surface) empathy

As explained above, the narrative significance and the emotional import of rock art is often in the composition of its scenes, regardless of how the animals are represented. The situation is, however, different when looking at an animal figure in isolation. Here the depiction technique is relevant to the emotional and empathic expressions the figure may articulate.

When looking at a lateral image of an animal in isolation, whether painted or engraved, there is no clue as to the empathic content, other than to say that the artistic sensation it may represent is primarily kinaesthetic (for kinaesthetic empathy, see Parviainen 2003; Fogtmann 2007; Achrati 2007). That is, viewed in profile, the isolated figure primarily invokes the bulk, weight, musculature, movement and distance of the animal in relation to the artist. The iconographic accomplishment of the image may also convey the sense of awe that inspired it and attended to its execution, as in the red drawing of a bear at Chauvet, or the images of bovids in the Saharan Atlas, Algeria.

Indeed, what most distinguishes iconic Palaeolithic art is that it is deeply kinaesthetic, stressing movement and articulating moving objects. Nearly all the depictions in cave and rock art consist of animate beings (animals and humans), while most of the identifiable objects are projectiles — arrows and spears. Plants are almost non-existent. Hunting, the predominant theme of this art, is also a kinaesthetic activity, combining exploration, tracking, chasing and shooting. The bestiary that is represented also lends itself neatly to a kinaesthetic categorisation along three dimensions: speed (horses), elegance of motion (reindeers, gazelles and giraffes), and massiveness (mammoths, rhinos, elephants) (Achrati 2007).

4.6 Deep empathy

By contrast, and because of perspective and foreshortening, a frontal picture of an animal, even in isolation, exposes more than one side of the animal (front, front and side, rear, rear and side, and rear and turned face), and increases the visibility of its expressive features and gestures. Frontal and rear views of an animal allow for different points of empathetic access and emotional exchange with the animal, and increase the sensory responsiveness of the beholder. As can be seen in Figures 7 and 8 this empathic exchange is most intense in frontal views when the animal gaze meets that of the beholder, a moment always fraught with dread or excitement. Animal fear and aggression are also signalled using the teeth and the mouth. A head turning to the back may indicate gaze avoidance, alertness or anxiety. The animal in these frontal or near frontal poses can also be performing a biological action which the beholder recognises, understands and identifies with, as in the picture of a cow licking its hind leg, or a giraffe or the gazelle scratching its head with its hind leg, or the three giraffes eating off a tree.

4.7 Mirror neurons and pictorial perspective

These frontal/near-frontal/rear images present visibly recognisable features and observable actions involving a goal-oriented movement (e.g. gaze, head motion, hind leg action), which, as indicated above, are within the human mirror repertoire, just like biting in the study of Buccino et al. (2004b). The beholder is also susceptible to experiencing the relief, comfort or satisfaction derived by the animal from self-grooming or mending an injury with its tongue. The beholder does not only recognise these actions, but he/she experiences a form of 'self-extension,' to use a phrase of Helvenston and Hodgson (2010: 69).

Once the artist's mirror-neuron system is done internally representing these observable actions in terms of 'motor ideas', affective resonance, or the artist's empathy, comes into play, heightening the demand for the motor and cognitive skills needed for producing a likeness of the selected action. This demand for kinematic congruence is further exacerbated by the artist's psychological pressure to avoid failed drawings. The stronger the empathy, the greater is the artist's tendency to avoid failure and the experience of dissonance, a condition which may also involve a subset of the mirroring cells, those with inhibitory property (*supra*).

In the end, these cognitive and sensorimotor constraints combined with the complexity of the kinematic task severely limit the representational options, leading to a minimal use of frontal and rear depictions of animals and the scarcity of these depictions even among the naturalistic styles of rock art.

5. Summary and conclusions

Attention to the role of the mirror neurons in the creative and artistic process provides new insights into the motor and cognitive processes involved in the production of rock art. It also underscores a need for a survey and categorisation of the empathic gestures of this art. From what has been said, the following hypotheses can be formulated:

1. The ability to use perspective to create vivid pictorial impressions of animals in various poses is a mimetic activity reflecting the visual and motor skills of the artist as well as a primal empathetic response to the animal, at the basis of which is the action of the mirror neurons.
2. There is a significant correlation between perspectival representations in rock art and the multivalence of empathy in this art. A lateral view of animals involves primarily a kinaesthetic empathy, which can still be very easily layered with emotional and intentional significances depending on its context and its pictorial narrative. By contrast, even in isolation, frontal and rear views of an animal

allow for multiple points of emotional exchange with the animal and are therefore empathically multivalent.

3. The embodied empathy implied in the action of mirror neurons approach calls for an understanding of rock art that is based on a multimodal structure of perception integrating not only visual but also haptic, proprioceptive, tactile, auditory and even gustatory inputs.
4. The fact that zoomorphic depictions far outnumber anthropomorphous (and floral) ones is certainly related to the role of animals as a source of subsistence. But — and this merely a thought experiment — the zoomorphic bias in rock art may also indicate the following evolutionary conditions:

a. Affect is biologically rooted in appetitive drives. Notice, for example, how disgust, which we express in the presence of bad food, bad situations and morally revulsive ideas, may have evolved as an oral defence to potentially harmful foods (Haidt et al. 1997).

b. Human cognitive and emotional development depended heavily on the carnivorous path that marked human evolution.

c. The zoomorphic bias in rock art may be a human attempt at resolving an aesthetic/moral ambiguity arising from the fact that animals are, at once, a source of food and an object of awe. That is, rock art can be thought of as an artistic tribute to the animal, and a sublimation of human sensibilities, which stands as the equivalent of the mythical restitution referred to in the ethnographic literature on hunting magic. As an aesthetic behaviour, therefore, rock art was a precursor to moral and religious development.

d. Possible support for this speculative hypothesis may be in the absence (to my knowledge) of cannibalistic scenes in rock art, as well as the absence/near-absence of rock art in societies where cannibalism was practised.

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