Dopaminergic systems expansion and the advent of *Homo erectus*

Alicia M. DeLouize, Frederick L. Coolidge, Thomas Wynn

**Abstract**

It is well accepted that a grade shift occurred in hominin evolution approximately 1.9 million years ago with the appearance of *Homo erectus*. With the challenges of complete terrestrial life, new cognitive abilities were selected for that allowed this species to thrive for the next million and a half years. It has also long been recognized that there was a change in diet with the advent of *Homo erectus*, that is, a greater reliance on meat. However, the relationship between additional meat and the cognitive abilities of *Homo erectus* has mostly remained unclear. The present paper proposes that an increase in dietary meat protein and fats may have led to an increase in dopamine and dopaminergic systems, a critical chemical neurotransmitter in the brain. This purported change in dopaminergic systems may have played a key role in many of the traits and abilities exhibited by *Homo erectus* at that time, including increases in body and brain size, dispersion, and a greater aptitude for spatial and social cognitions.

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### 1. Introduction

Although the genus *Homo* semantically begins with the origins of habilines about 2.5 million years ago (Ma), there is a general consensus that a major grade shift occurred in hominin evolution beginning with *Homo erectus* about 1.9 Ma. The brain size of *Homo erectus*, about 900 cc to 1,000 cc, approaches the lower limits of modern *Homo sapiens*, about 1,000 cc to 2,000 cc (average = 1,350 cc). In addition, although the habilines are associated with the first stone tools, the stone tools of *Homo erectus* are thought to be more sophisticated technically, cognitively, and aesthetically (e.g., Wynn, 1989, 2002). Their bifacial and symmetrical design was to persist for the next million years and more. More critical, especially in terms of the evolution of modern cognitive abilities, may have been the full transition of *Homo erectus* to life on the ground instead of a life in trees. Coolidge and Wynn (2009) proposed that modern human cognitive abilities appear to have evolved in two major leaps (Coolidge and Wynn, 2006) with the first being the advent of *Homo erectus*, which is marked behaviorally by an expansion of territories, responses to ecosystem change, increased sociality, and increases in spatial cognition (e.g., Antón, 2003).

Explanations for *Homo*’s increase in relative brain size and abilities have focused on the energetic costs of large brains (Pontzer, 2012). There is a direct relationship between number of neurons and caloric requirements (Fonseca-Azevedo and Herculano-Houzel, 2012), a link that could possibly be related to protein calorie nutrition, as a lack of dietary protein has been shown to lead to a decrease in brain weight and in the protein content of the brain (Lucas and Campbell, 2000). Thus, an evolutionary increase in brain size must have been accompanied by an increase in accessible calories, either by a change in dietary quality, an increase in time spent foraging, or a change in the way calories are stored. In 1995 Aiello and Wheeler (1995) made a strong case for the ”expensive tissue hypothesis,” arguing that early *Homo* paid for” the increase in neurons via a dietary shift to meat, which is a higher quality food (more concentrated calories) than the plant foods that form the majority of the diet for most apes, including early hominins. They further argued that the dietary shift would have been accompanied by a decrease in the length of the gut; because the gut is also an “expensive tissue,” it would be difficult for hominin physiology to support both. Digesting meat requires shorter guts than digesting plants, and thus a reduction in gut length would naturally accompany the dietary shift or, a stronger version of the argument, require the dietary shift. The modern human gut also appears to be adapted to cooked foods (Wrangham...
et al., 1999; Wrangham, 2009). Wrangham argues that in the absence of cooking, the sheer amount of chewing time required to process meat would have limited its usefulness as a high-quality food. He argued that Homo erectus adopted fire for cooking; cooking both makes meat easier to chew and easier to digest. Earlier Homo processed meat by pounding (there is extensive evidence for pounding tools at the 1.75 Ma site of FLK (Mora and de la Torre, 2005)). Complicating the picture even further is the possible role of body fat, which is higher in humans than apes, as a buffer against dietary stress, and thus a possible factor in increased brain size (Anton and Snodgrass, 2012; Anton et al., 2014; Roberts and Thorpe, 2014). What seems clear is that the 30% increase in brain size over Australopithecus required some kind of dietary/adaptive shift. The contemporaneous archaeological evidence for butchery makes a strong circumstantial case that this dietary shift included meat.

This increase in consumption of meat also provided the precursors necessarily to significantly increase dopamine, a chemical neurotransmitter in the brain, and when combined with ecological pressures could have led to an expansion of dopaminergic systems. Previc (1999), appears to be the first to propose that this change in the hominin diet was the critical precursor to the expansion of the dopaminergic system that may have led to a revolutionary cascade of changes in later Homo cognition. Evolution of the dopamine system has been sporadic since mammals first evolved, and may have also been an important part of the evolution of the Homo genus (Previc, 2009). Dopaminergic systems have been shown to be important to essential modern human behaviors, particularly motor movements and cognition. In particular, it systemically and neurologically allows for thermoregulation, novelty seeking, sociality, handedness, increases in REM sleep, goal achievement and reward, behaviors that are thought to have arisen or increased during the grade shift that led to Homo erectus (Fig. 1).

Some aspects of the dopaminergic system, as well as complex traits that arise from such systems are only possessed by Homo sapiens. When comparing the human genome to the chimpanzees, the D5 dopamine receptor in humans has an unusually large number of DNA sequence changes, pointing to adaptive evolution (e.g., Somel et al., 2013). Given D5 receptors co-localization with known dopaminergic pathways, it is thought to play an active role in dopaminergic neurotransmission (e.g., Khan et al., 2000). It has also been amply demonstrated that dopamine is found in high concentrations in the dorsal lateral prefrontal cortices and the anterior cingulate cortices. There is substantial empirical evidence that these regions play critical roles in working memory and its executive functions, attention, and goal-directed behavior, traits long thought to contribute to human intelligence. Furthermore, these cognitive processes are known to serve a foundational basis for higher human reasoning, such as fluid intelligence (the ability to solve novel problems).

2. Meat eating and Plio-Pleistocene Homo

Sometime about 1.35 Ma, a group of Homo erectus butchered a number of large mammals at a site at Olduvai Gorge, including an elephant, a hippopotamus, a rhinoceros, a Sivatherium (related to modern giraffe), and two Pelorovis (related to Cape Buffalo). There is no evidence that the hominins killed the animals, and scavenging was the likely means by which they accessed the carcasses. Remains at the site (BK) also include bones from small and medium sized mammals, which may have been hunted. Percussion and cut marks on the bones confirm extensive butchery of all of the remains. Clearly, meat had come to be an important part of the Homo erectus diet (Dominguez-Rodrigo et al., 2014).

Homo erectus was not the first hominin to butcher animals for meat. 400,000 years earlier another group of hominins butchered animals at Olduvai Gorge. The site at FLK has famously yielded evidence for butchery of small to medium sized mammals, with an especially distinct focus on extracting marrow from long bones (Bunn and Kroll, 1986; Bunn et al., 2010; Dominguez-Rodrigo et al., 2011). Here the taxon of the butchers is not clear; the one fossil hominin recovered from the site was the skull of a Paranthropus, but many consider it to have been not the butcher, but one of the butchers. An early form of Homo, Homo habilis, occurs in deposits of the same age at Olduvai, and thus was the presumed butcher at FLK (Wood, 2014). Homo habilis used sharp flakes struck from lava cores to butcher meat from the scavenged carcasses, and the cores themselves to break open the long bones for marrow.

Stone tools such as cores, flakes, and hammer stones allow paleoanthropologists to trace presumed butchery even further back in time than the examples from Olduvai Gorge. Recently archaeologists have pushed back the oldest known tools to the 3.3 million-year-old site of Lomekwi 3 in northern Kenya (Harmand et al., 2015). There was no butchered bone at Lomekwi, but the slightly older site of Dikika in Ethiopia has yielded possibly cut marked bone, but no artifacts (McPheron et al., 2010). The 2.6 million-year-old site of Gona (Semaw et al., 2003), and the 2.3 million-year-old site of Lokalalei (Roche et al., 2003; Delagnes and Roche, 2005) have yielded both stone tools and cut marked bone. It thus appears as if butchery was a component of hominin adaptations prior to the first appearance of Homo erectus 1.8 Ma (Anton and Snodgrass, 2012; Anton et al., 2014). The hominin evident at Dikika was Australopithecus aferensis, and the nearest time/space associated hominin for Lomekwi was Kenyanthropus platyops, another smaller brained form (Harmand et al., 2015). Thus, Australopithecus grade hominins were the first to develop knapped stone technology, and also the first to make a shift toward reliance on meat from scavenged carcasses.

Brain expansion is the primary anatomical criterion that distinguishes the genus Homo from earlier hominins such as Australopithecus, yet the picture of when and where early Homo evolved is far from clear. Fossil evidence indicates that there were at least three different varieties of early Pleistocene Homo living in East Africa between 2.5 and 1.5 Ma. The two seemingly earlier varieties, assigned by some to Homo habilis and Homo rudolfensis, had brain sizes that were on average 30% greater than penecontemporaneous Australopithecus and Paranthropus. These two Hominos differ from one another in regard to facial characteristics and body size (Anton et al., 2014). However, because the sample sizes are so small, other paleoanthropologists take a more cautious approach to this variability and lump all of these remains into a single, polytypic taxon (Anton and Snodgrass, 2012). Homo erectus itself is often divided into an African variety, Homo ergaster and an Asian variety, Homo erectus sensu stricto. The 1.85 Ma site at Dmanisi in the Caucasus Mountains complicates taxonomy even more, with five quite variable individuals, some of which are erectus-like and others more similar to habilis (Anton et al., 2014). While all of the above had larger brains than Australopithecus, it is not clear which were responsible for the butchery at Gona and FLK. For purposes of this discussion, then, we will lump all of them together into a single evolutionary grade of early Pleistocene, large brained, hominins — early Homo sensu lato.

3. How meat could have led to dopamine expansion

The brain is known as one of the most expensive tissues metabolically, as evidenced by the fact that the human brain makes up only 2% of its mass, yet it consumes approximately 20%–25% of its energy expenditure. Given that larger brains require more
energy, this expansion of the diet has long been thought to have been one of the causes for the grade shift, however, to date, the neural and nutritional mechanisms remains unclear (e.g., Coolidge and Wynn, 2009; Pante, 2013). It can be assumed that meat caused an increase in phosphorylation, which is a process that activates and deactivates many protein enzymes, thereby profoundly altering their function and activity in a vast range of important cellular processes. One obvious repercussion of increased phosphorylation is an increase in adenosine triphosphate (ATP; chemical energy), a coenzyme energy carrier which occurs in all known organismic cells. However, meat may have also fostered the increase in brain size and cognitive abilities in another way: by increasing the production of dopamine.

Many studies have shown that dietary changes in protein and fat consumption lead to an increase in both dopamine, by converting tyrosine into the dopamine precursor levodopa, and to an increase in the expression of other dopamine related genes, including other dopamine receptors (Montgomery et al., 2003; Lee et al., 2010; Vucetic et al., 2010) and increases in a dopaminergic phenotype (Harmer et al., 2001). Tyrosine can easily be turned into dopamine, using just two enzymes, tyrosine hydroxylase, and DOPA decarboxylase. The rate limiting step of this conversion is the hydroxylation of tyrosine, which depends on the availability of this amino acid (Fig. 2). Therefore a diet higher in tyrosine can create more dopamine. Additionally, administration of levodopa increases glial cell line derived neurotrophic factor (GDNF), which leads to the

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**Fig. 1.** A complex feedback loop between meat consumption, environmental pressures, increased dopaminergic systems, and the behaviors that arise from them exists. Many of the changes seen in the archeological record could have been aided by, or attributed to, dopaminergic systems.
protection of dopamine neurons, tissue reorganization, plasticity, and recovery of lost dopaminergic functioning due to injury or disease (Kuric et al., 2013). Since the brain starts with many more neurons than it needs at birth and selectively prunes off millions of neurons in the first few years of life, an increase in levodopa could have significantly increased the number of dopaminergic neurons by preventing less from undergoing apoptosis, or regulated cell death, during these early years. This selective pruning system destroys synapses and neurons that will not be useful based on their low inputs. Natural selection can easily act on this system by keeping neuronal pathways that provide survival benefit or other advantages, as well as creating more pathways through neurogenesis both in vivo and, to a lesser extent, throughout life. In addition to preventing neuronal death and promoting regeneration, the administration of levodopa can also cause the up-regulation of dopamine receptors (Cote and Kuzhikandathil, 2015) and activation of dopaminergic neurons has been shown to increase certain dopamine receptors (Carcenac et al., 2015). Thus, an increase in tyrosine, which is found readily in meat, could have led to an increase in dopaminergic systems by increasing dopamine, dopamine receptors, dopamine neurons, and dopaminergic pathways in the brain.

Because of dopamine's involvement with reward, behaviors that arise from this system are often felt as being pleasurable, and therefore one is more likely to engage in them in the future. Three major dopaminergic pathways, the nigrostriatal pathway, the mesocortical pathway, and the mesolimbic pathway all promote reward learning (Wise, 2009), and when these systems get out of hand behaviors can become addictive. This creates a feedback loop in which behaviors that arise from the dopaminergic system are rewarding, therefore they are continued or increased, causing more dopaminergic activation, which then leads to the creation of more dopaminergic systems. This feedback loop, combined with selection of useful traits and behaviors that arise from the dopaminergic system, could have led to some of the traits and behaviors that evolved in early Homo.

Another method for increasing dopamine production without explicit change in the sequence of nuclear DNA is epigenetics. Epigenetics is a group of cellular events, outside traditional DNA/RNA transmission, that results in inheritable changes across generations. In this manner, the environment can interact and affect the genome through changes in chromatin (potentially leading to gene activation and/or inactivation), androgen silencing, and other factors that lead to changes in subsequent gene functions. Such epigenetic mechanisms are easily selected upon due to the fact that mothers who eat meat expose their embryos during gestation to higher levels of tyrosine which in turn leads to a greater synthesis and postsynaptic activity of dopamine in the central nervous system of their offspring (e.g., Santana et al., 1994; Previc, 2009). Given that genetic mutations happen randomly and at a relatively fixed speed, epigenetic transmission is possibly a faster mode of transmission than genetics alone, allowing for a host of changes in a relatively short amount of evolutionary time, which appears the case between the australopithecines and Homo.

4. Dopamine and the expansion of territories

Interestingly, another behavior that has been shown to increase dopamine levels in the brain is physical exercise. An increased metabolic rate during exercise also converts tyrosine to the dopamine precursor levodopa, which then appears to cause a series of events, ultimately leading to increased dopaminergic signaling in the hypothalamus. The hypothalamus controls a host of critical life functions, including body temperature, hunger and thirst, parent-child bonding/attachment, fatigue and sleep, and circadian rhythms. Increased dopaminergic signaling may also occur in the nigrostriatal pathway during exercise, which controls thermoregulatory autonomic effects and the efficiency and execution of motor movements (e.g., Scally et al., 1977; Brannan et al., 1991; Fernandes et al., 2012). Also, animal models have shown D1 and D2 dopamine receptors lower body heating rate, prevent hyperthermia, increase exercise performance, and increase the volume of oxygen that can be inspired (e.g., Lee et al., 1986; Balthazar et al., 2010; Iwase et al., 2013). An increase in thermoregulatory functions and exercise performance might have provided some of the physiological traits necessary for the huge expansion of territories, often in disrupted environments, of Homo erectus near the beginning of the Pleistocene era.

Further, Bramble and Lieberman (2004) have shown that the skeletons of Homo erectus were ideal for endurance running. Endurance running would have had two important sequelae: (a) an expansion of territory, and (b) persistence hunting. Klinker et al. (2013) noted that although some types of mice experienced a training effect in which they could run faster, longer distances, and longer periods with practice, mice without D2 receptors could not benefit from the training effect. These changes were thought to be behavioral in nature and not simply motor deficits because previous research had shown that D2 receptor deficient mice could learn to increase motor activity when provoked (Kelly et al., 1998). Also, the mice were noted to have the same motor behaviors when compared to mice without D2 receptors in activities such as grooming and climbing. Given that dopamine receptor activity could lead to an increase and improvement in running which then takes advantage of increased dopamine as a thermoregulator due to an increase in activity, a feedback loop could be established which might further encourage and select for increased dopaminergic systems and dopaminergic innervation.

In addition, dopamine signaling in the hypothalamus and nigrostriatal pathway has long been shown to be associated with behaviors such as novelty-seeking and exploration (Cloninger, 1987). More recently, scientists have been able to identify these systems as critical to many motivational processes including behavioral activation, sustained drive to achieve distant goals, approach behavior, exertion of effort, Pavlovian processes, and instrumental learning (e.g., Hills, 2006; Salamone and Correa, 2012;
Howe et al., 2013). In addition, dopamine has been shown to correlate with an increase in novelty and behaviorally induced motor activity (e.g., Fernandes et al., 2012; Klinker et al., 2013). The blockage or removal of the D2 dopamine receptors in mice results in a decrease in spontaneous/voluntary locomotor activity (as measured by a running wheel system) (Klinker et al., 2013). These may be some of the reasons why the frequency of certain dopamine receptor genes and personality traits in a population are correlated with the distance it has moved from its original location (Campbell and Barone, 2012). Thus, there is sufficient evidence from animal models and in modern humans to suggest that increased dopaminergic signaling in Homo erectus could have provided and enhanced the behavioral traits that would have been needed to expand into and explore new territories.

5. Dopamine and visuospatial functions

While the two cerebral hemispheres are highly synchronous in their functioning for nearly all tasks, visuospatial tasks are primarily processed by the right hemisphere (e.g., D'Esposito et al., 1995). Given the more ancient nature of humans' visual and spatial cognitive abilities, which were critical to the successful evolution of primates over about 60 million years, the present paper proposes that enhanced visual and spatial functions were favored and selected for in the transition between the australopithecines and Homo erectus, and it is further proposed that they evolved separately from other cognitive systems such as language and general systems of memory. This proposition is consonant with the current supposition that Homo erectus had more complex visual and spatial cognitive abilities than their evolutionary predecessors. The latter, of course, would allow their Homo erectus two defining behavioral characteristics: (1) it allowed them to navigate larger stretches of land, and (2) they were able to create and improve the more spatially complex bifacial hand axe design (Fig. 3).

Along with other forms of working memory, dopamine has long been shown to be the key player in visuospatial working memory, which is the ability to update and reference visual and spatial information while performing a spatial task (e.g., Glickstein et al., 2002; Reeves et al., 2005). It has been shown, for example, that when the dopamine pre-cursor levodopa or a placebo were administered to a group of young and older adult volunteers, although the young adults initially performed better on a motor training task in both groups, only the administration of levodopa led to an acceleration of the memory encoding process. Interestingly, older adults who received levodopa had enhanced motor memory abilities comparable to baseline rates of the younger cohort (Flöel et al., 2005). This study may serve as preliminary evidence that meat could have had a direct influence on improving spatial reasoning, particularly after consumption. The direct effects of improved spatial working memory provide a behavioral advantage that could be selected upon to further enrich dopaminergic systems across generations.

6. Dopamine and sociality

Dopamine has long been known to be associated with extraverted behavior (e.g., King et al., 1986; McClelland et al., 1987). Depue and Collins (1999) described extraversion as interpersonal engagement, which may have two main components: (1) affiliation, which is enjoying and valuing relationships and being affectionate, and (2) agency, which is being dominant, assertive, and accomplishing goals. They also empirically demonstrated that dopamine contributes to all of these behaviors and proposed that this may be because of dopamine’s role in positive incentive motivation. An increase in interpersonal engagement, affiliation, and agency all might have helped Homo erectus to establish mating networks because of their expanding territories (Coolidge and Wynn, 2009) and would have undoubtedly aided pair bonding, which may have arisen or increased in prevalence during this time period (Aiello and Key, 2002; Coolidge and Wynn, 2009).

Humphrey (1976) was one of the first to note that complex social interactions may be correlated with humans broad range of problem solving abilities, including the Machiavellian theory of intelligence (e.g., Byrne and Whiten, 1988). Machiavellian intelligence is thought to be required to successfully navigate complex
polyadic relationships, in which one must keep track of numerous players, each having their own agency and perceptions, and which must have been an integral part of the evolution of human intelligence. Dunbar (1992) and others have found a correlation between group size and cortex size, which suggests that increased computational power is needed to navigate larger groups. If it is true that social and cultural interactions are a critical foundation for the evolution of human intelligence (e.g., Shultz and Dunbar, 2010), then dopaminergic system expansion might have substantially aided in the process.

Another trait shown to be correlated with larger group size is laughter (Dezecache and Dunbar, 2012). It is thought to aid in one’s ability to interact with more players at the same time through the projection of a general social signal that others may join in on, due to its contagion. Laughter has been shown to arise from the mesolimbic dopamine system, which is the dopaminergic system most utilized in reward behaviors. Laughter is found in many of the great apes, it was thought to have first arisen over 6.5 million years ago. However, this form of laughter is described as more of a pant, and it is not elicited in as many situations as human laughter is today (Gervais and Wilson, 2005). It is thought that when apes became bipedal it alleviated pressure on the thorax and vocalizations were no longer coupled with breathing (Aiello, 1996; Provine, 2000; Gervais and Wilson, 2005), allowing for an increase in the utility of laughter at a time when the human lineage was becoming more social as evidenced by growing group sizes. Therefore, many believe that laughter as we know it evolved between 2 and 4 million years ago (Gervais and Wilson, 2005), the same time frame that meat became a more important part of the hominin diet and Homo erectus evolved.

In addition, numerous studies have shown that greater levels of dopamine in the brain are correlated with increases in extraversion (e.g., King et al., 1986; Wacker et al., 2006; Golimbet et al., 2007). Extraversion is a trait apparently critical to be able to successfully interact with others interpersonally and to be able to interact successfully from group to group. These social traits seem to be integrated with the dopaminergic reward system, further spreading the behaviors and allowing for hominin group size to grow at a time where cooperation and protection were essential for survival. The greater innervations of the dopaminergic system may have allowed hominins to interact with others in ways they had not before.

7. Dopamine and improved sleep

Coolidge and Wynn (2006) have put forth another interesting hypothesis regarding the sleep of Homo erectus. They proffered that when Homo erectus began sleeping on the ground, it removed selection against longer rapid-eye-movement (REM) sleep, and it may have provided for a single, integrated sleep period with slow-wave sleep predominant initially in a single sleep period. REM sleep is highly synonymous with vivid dreaming. Dreaming is often associated with creative ideas and innovation (e.g., Hartmann et al., 1998, 2001; Coolidge, 2006), a rehearsal of threats and difficult social situations, and a consolidation of procedural motor memories and visuospatial locations (e.g., Maquet et al., 2003). All these behaviors are associated with creative ideas and innovation (e.g., Hartmann et al., 1998, 2001; Coolidge, 2006), a rehearsal of threats and difficult social situations, and a consolidation of procedural motor memories and visuospatial locations (e.g., Maquet et al., 2003). All these behaviors (creativity, threat rehearsal, and consolidation of visuospatial memories) may have subsequently primed Homo erectus for more success in their daily activities (e.g., Revonsuo, 2000; Franklin and Zylphur, 2005). Moreover, dopamine plays a key role in sleep cycles. It has been shown that dopaminergic degeneration is positively correlated with a decrease in REM sleep (Proenca et al., 2013). In addition, both Ferreira et al. (2002) and Lee et al. (2007) found that administration of levodopa reduces sleep onset time and improves the quality and length of sleep. Therefore it is possible that an increase in REM sleep could have accompanied the possible dopaminergic systems expansion during this time period.

8. Dopamine and cerebral lateralization

Another change that occurred during the early evolution of the Homo lineage was tools made by Homo erectus started to show a clear right-hand preference of their makers (Uomini, 2009). Previously, it was thought that right hand preference was due to the left hemisphere’s specialization for language, but most anthropologists suspect that a grammatical, symbolic language may not have arisen for another million years or more (e.g., Fitch et al., 2005; Coolidge and Wynn, 2009). Further, the specialization of language resides in the left hemisphere for nearly all right-handed people and most left-handed people. Due to these contradictions and others, a recent review of the lateralization literature concludes that handedness and language lateralization were most likely independently derived (Fitch and Braccini, 2013). In addition, there is some tantalizing research that shows that handedness is more reliably traced to cerebral dopamine asymmetries than to language specialization (e.g., de la Fuente-Fernández et al., 2000; Mohr et al., 2003; van der Hoorn et al., 2012). Fascinatingly, people physically turn their bodies away from the side of their brain that has more dopamine (Mohr et al., 2003). This relationship is so well established that turning behavior alone is often taken as proof of dopamine asymmetries in humans. Further, animal models demonstrate that the dopaminergic system is linked to handedness. Injecting dopamine into the brains of rats produced an increased use in the preferred paw when injected on the same side and a decreased use in the preferred paw when injected on the opposite side (Evenden and Robbins, 1984). Not only is there a strong relationship between dopamine asymmetries and handedness, but also varying levels of dopamine activity affected the intensity of this lateralization (Cabil et al., 1995). The relationships between dopamine asymmetries, turning behavior, and handedness have also been established in mice (Nielsen et al., 1997). Thus, the interesting relationship between hand preference and dopamine may be another enticing piece of evidence that dopaminergic expansion may have occurred in the evolution of Homo erectus.

9. Conclusions

It is important to note that the change in diet that precipitated these events likely did not cause this dopaminergic expansion directly. However provided the precursors necessary to select for increased dopaminergic systems due to pressures caused by the changing environment and dopamine’s deep seated roots in reward learning. In addition, neurotransmitters have inhibitory interactions with, and can easily be converted into other neurotransmitters, therefore the evolution of this system most likely coincided with the evolution of other brain systems in a complex and non-linear evolutionary process. Despite only being one piece of the puzzle, dopaminergic systems expansion could have played an important role in the creation of our genus by allowing for a host of adaptations that enabled survival in a changing environment.

In summary, the present paper has presented neurophysiological and behavioral evidence that dopaminergic expansion could have played an important role in the cognitive evolution of Homo erectus. Given that there was a major grade shift in hominin evolution, coincident with increased meat in Homo diets, there appears to be an increased likelihood of an integral relationship between the two, which should be further explored. In addition to providing more energy, meat provides the precursors
necessary for increases of dopamine in the brain, and increased dopamine has been shown to aid in thermoregulation, exercise, novelty-seeking behavior and exploratory behavior, increased visuospatial abilities, single integrated sleep periods and extended REM sleep, increased sociality (extraversion), and hand preference. All of these characteristics may have played a critical role in the grade shift that led to Homo erectus, and all may have arisen along with a dopaminergic systems expansion during this time.

References


