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The Cognitive Evolution of Homo erectus

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The Cognitive Evolution of *Homo erectus*

Cognitive evolutionary archaeology applies theories of cognitive sciences to archaeological remains and artifacts uncovered throughout paleo-history in attempts to infer the cognitive capacities for the production and refinement of material objects (Coolidge & Wynn, 2016). Established through sedimentary discoloration in Koobi Fora, Kenya, the first usage of fire for cooking occurred around 1.6 million years ago (mya) at the FxJj20 Site complex (Andrews & Johnson, 2020; Anton, 2003; Hlubik et al., 2013; Ungar, 2012; Van Arsdale, 2013). Evidence from this site suggests it was the habitat of *Homo erectus,* which first appeared approximately 2.5 mya (Andrews & Johnson, 2020; Anton, 2003; Bramble & Lieberman, 2004; Previc, 1999; Semaw et al., 2020; Ungar. 2012; Van Arsdale, 2013; Wynn, 2002) indicating they utilized fire for food preparation. Cooking no longer required hominins to deactivate digestive inhibitors themselves (Ragir, 2000) resulting in quicker energy yield from the same volume of meat and other foods (Andrews & Johnson, 2020). Greater protein and fat-based diets have been shown to increase the amount of dopamine within the brain (Lee et al., 2010; Somel et al., 2013) which is involved in a myriad of physiological and behavioral functions that have arisen such as larger bodies and larger cranial cavities (Blum et al., 2012; Carcenac et al., 2015; Cota & Kuzhikandathil, 2015; DeLouize et al., 2016; Kuric et al., 2013; Lee et al., 2010; Matsumoto et al., 1999; Nieoullon, 2002; Previc, 1999; Salamone & Correa, 2012; Saper & Lowell, 2014; Somel et al., 2013; Wurtman, 1983). This dietary shift from raw to cooked meats and its concomitant incorporation of higher amounts of dopamine in *H. erectus* is believed to have been paramount to their encephalization aiding in their cognitive and behavioral evolution.

H. erectus is the earliest hominin scholars are aware of using fire in cooking their game (Andrews & Johnson, 2020; Anton, 2003; Carotenuto et al., 2015; Hlubik et al., 2019; Ragir, 2000; Ungar, 2012). Many benefits came along with the manipulation of fire, such as reducing the extrinsic mortality rate by deterring predators and killing foodborne pathogens decreasing the presence of disease (Ragir, 2000; Wrangham, 2009; Wrangham & Carmody, 2010). Additionally, fire bypassed the manual need of *H. erectus* to chew its food through its own means of nutritional fracturability far exceeding the digestibility and net energy gain achieved by past hominins (Ragir, 2000; Wrangham & Carmody, 2010). This difference in preparation led to physiological changes along with protection from external factors. Diminution of plant-based matter and popularization of meats demanded less energy expenditure on their digestive tract and subsequently reduced the gut size of *H. erectus* (Aiello & Weaver, 1995; Andrews & Johnson, 2020; Roberts & Thorpe, 2014) as well as downsized post-canine dentition (Andrews & Johnson, 2020; Pontzer et al., 2012; Previc, 1999:318; Ungar, 2012; Van Arsdale, 2013). Another physiological change was seen in their cranial structure appearing roughly 50 percent larger than earlier australopiths (Somel, et al., 2013; Van Arsdale, 2013) and measuring proximately 800 ccs to 1,000 ccs (Anton, 2003; DeLouize et al., 2016; Rightmire, 2004; Rightmire 2013; Somel et al., 2013). The significance of greater brain volume is due to the crucial aforementioned actions which prompted the growth, and the proceeding effects it had on hominid lifestyles.

The Brain and Dopamine

The brain is a metabolically expensive tissue consuming about 20 percent of the body's energy therein requiring a higher caloric intake to maintain a steady basal metabolic rate (Aiello & Wheeler, 1995; Navarrete et al., 2011; Hills, 2006; Somel et al., 2013; Van Arsdale, 2013), believed to have been fulfilled for *H. erectus* through cooked meats (DeLouize et al., 2016). Currently, it is known that phosphorylation, a biochemical process of enzyme activation and deactivation, can be increased by meat resulting in altered enzyme functions in a variety of vital cellular processes (DeLouize et al., 2016; Freeman, 2002:270). One example is an increase in adenosine triphosphate, an energy-carrying molecule found in the cells of all known living organisms (DeLouize et al., 2016:247; Freeman, 2002:141-146). However, research is still in progress to understand the explicit neurological mechanisms for how meat contributed to this evolutionary change of brain enlargement (DeLouize et al., 2016, Previc, 1999:327; Wrangham, 2009). Another possibility for how meat assists in brain growth is through the production of the neurotransmitter dopamine (DeLouize et al., 2016; Previc, 1999; Santana et al., 1994). DeLouize et al. (2016) proposed that the cooked high-calorie protein diet of *H. erectus* led to a more elaborate dopaminergic system and consequently their larger brain size.

Dopamine levels have been shown to rise with dietary practices high in proteins and fats, which are abundantly present in meat (Lee et al., 2010; Previc, 1999). Meat's role in the dopaminergic release is through the synthesis of its nutrient tyrosine by the dopaminergic precursor levodopa (Blum et al., 2012; DeLouize et al., 2016; Previc, 1999). Therein shows the chronic ingestion of diets high in protein and rich in tyrosine correlates directly to the involvement of more dopamine and inevitably elevating dopaminergic levels in the central nervous system (CNS) (DeLouize et al., 2016: Previc, 1999: Wurtman, 1983). On top of converting tyrosine to dopamine, levodopa is responsible for increasing the glial cell line-derived neurotrophic factor (GDNF) protecting the dopaminergic neurons and aiding in their revitalization (Blum et al., 2012; DeLouize et al., 2016; Kuric et al., 2013). Upregulation of dopamine receptors can be contributed to levodopa too (Cote & Kuzhikandathil, 2015; DeLouize et al., 2016). Brain development begins with the presence of an oversupply of neurons necessary for a neonate and therefore exposed to a pruning process of synapse and neuron eradication by natural selection (Anton, 2003; DeLouize et al., 2016; Previc, 1999). However, natural selection can effortlessly direct the system to retain those beneficial to survival and generate additional pathways and neurons through neurogenesis (DeLouize et al., 2016; Previc, 1999; Somel et al., 2013). Hence, the prevalent presence of tyrosine would not have only increased dopamine but supported the foundational processes for dopaminergic self-regulation and renovations.

Established to be the most substantial reward neurotransmitter pathway in the brain is dopamine (Blum et al., 2012; DeLouize et al., 2016; Depue & Collins, 1999; Golimbet et al., 2007; Hills, 2006; King et al., 1986; McCrae & Costa, 2008; Nieoullon, 2002; Lee et al., 2010; Previc, 1999; Schulkin & Raglan, 2014; Wacker et al., 2006). Dopamine is found to significantly influence the left cerebral hemisphere in rewarding positive behaviors (de la Fuente et al., 2000; Golimbet et al., 2007; Kuric & Rushcer, 2013; Matsumoto et al., 1999; Previc, 1999; Somel et al., 2013). The left-lateralized hemisphere governs an untold number of functions including thinking, long-term planning, (Nieoullon, 2000; Previc, 1999; Matsumoto et al., 1999; Somel et al., 2013; Wynn, 2002) language, (Dunbar, 2003; Schulkin & Raglan, 2014) and rhythm (Lafarga, 2016; Robinson & Solomon, 1974). Reward-seeking behaviors are contributed to three major dopaminergic systems: the nigrostriatal pathway, the mesocortical pathway, and the mesolimbic pathway, all of which stimulate reward incentive behaviors (DeLouize et al., 2016; Nieoullon, 2002; Salamone & Correa, 2012). The nigrostriatal system is imperative in motor functionality and higher-cognitive functioning (de la Fuente-Fernández et al., 2000; DeLouize et al., 2016; Matsumoto et al., 1999; Nieoullon, 2002; Previc, 1999); emotional response, sensory changes to environmental shifts, and motivation are controlled by the mesocortical system (DeLouize et al., 2016; Nieoullon); and the mesolimbic pathway is the most significant of the three for the transfer of dopamine (DeLouize et al., 2016; Salamone & Correa, 2012). The combination of these dopamine systems creates a pattern of behaviors wherein actions that arise from the dopaminergic system are rewarding and therefore continue the pleasure-seeking behaviors resulting in the genesis of more dopamine into the system encouraging the cyclical repetition.

To summarize, the brain size of *H. erectus* is unarguably larger than previous hominins and direct causal mechanisms are still being debated. Cooked meats provided the metabolically expensive brain with sufficient energy for survival and flooded the neurological system of *H. erectus* with dopamine. DeLouize et al. (2016) suggested the surge of dopamine from cooked meats was a key contributor to the drastic difference in brain size. The dopaminergic expansion would have strengthened the dopamine pathways necessitating bigger brains while also stressing the continuance of pleasure-seeking behaviors.

Exercise and Persistence Hunting

Physical exercise and sexual relations are additional actions that have resulted in raised levels of dopamine in the brain (DeLouize et al., 2016; Graf et al., 2019; Hills, 2006; Hull et al., 2004; Oei et al., 2012; Previc, 1999). Increased metabolic rates induced by organisms convert tyrosine to levodopa and seemingly result in the signaling of dopamine to the hypothalamus (DeLouize et al., 2016; Graf et al., 2019; Hills, 2006; Hull et al., 2004; Previc, 1999; Salamone & Correa, 2012). It has been proven the hypothalamic neural circuitry controls a multitude of essential life functions for survival including metabolic control and energy expenditure, reflexive responses to environmental stressors or threats, hunger and thirst, and thermoregulation (DeLouize et al., 2016; Previc, 1999; Saper & Lowell, 2014). During physical activities, dopamine is also signaled to the nigrostriatal pathway facilitating control of thermoregulation and effectuating motor lateralization (de la Fuente-Fernández et al., 2000; DeLouize et al., 2016; Matsumoto et al., 1999; Nieoullon, 2002; Previc, 1999). A positive correlation between brain size and heat generation has presented a unique thermal challenge for *H. erectus* that previous hominins and primates did not face (Anton, 2003; Carotenuto et al., 2016; Previc, 1999).

Adaptions for thermal tolerance allowed persistence hunting of game in the arid savanna and made it possible to chase the target into a hyperthermic state consequently killing it (Previc, 1999). Pursuing a game in this manner would not have been feasible if not for *H. erectus'* bipedal adaptations for long-distance endurance running (Bramble & Lieberman, 2004; Steudel-Numbers et al., 2007; Van Arsdale, 2013; Wrangham & Carmody, 2010). Acquisition of the bipedal posture limited the radiating heat impact when the sun reached its pinnacle (Andrews & Johnson, 2020; Previc, 1999; Wrangham & Carmody, 2010). Selection of bipedalism additionally led to taller statures coinciding with increased body-to-mass proportions (Previc, 1999; Rightmire, 2004) therein fostering greater evaporative heat loss (Andrews & Johnson, 2020; Previc, 1999; Wrangham & Carmody, 2010). The absence of the typical heavy coats of past hominins permitted *H. erectus* to accumulate supplemental sweat glands than previously possible (Previc, 1999). Therefore, the high rates of evaporative stress required a severely more rapid system of dopaminergic signaling to the hypothalamus for activation of the newly adopted thermoregulatory properties.

Successful persistence hunting required well-developed extraversive behaviors of sociability which have long been known to be correlated with dopamine (Depue & Collins, 1999; Depue & Fu, 2013; Golimbet et al., 2007; King et al., 1986; McCrae & Costa, 2008; Wacker et al., 2006). Extraversion is a behavioral trait reflective of individual personality differences and evolved heavily from the mesocorticolimbic dopamine structure (Depue & Collins, 1999; Depue & Fu, 2013; Wacker et al., 2006). Extraversion is composed of energetic and outgoing characteristics affiliated with upbeat feelings including excitement, enthusiasm, optimism, and a strong motivational desire (Depue & Collins, 1999; Depue & Fu, 2013; Wacker et al., 2006). The mesocortical pathway orchestrates motivation and the mesolimbic pathway is instrumental in the transference of dopamine, therefore the joint mesocorticolimbic system was a fundamental component of the inception of hominin extraversion. Thus, cooperative and communicative actions stemming from the expression of extraversive characteristics interrelated with dopamine must have been demonstrated by *H. erectus* to have habitually procured sufficient game to sustain their observed larger living groups (as evidenced in Ileret, Kenya by Hatala et al., 2016).

In sum, copulation and physical exercise by *H. erectus* released dopamine which was signaled to the hypothalamus for modulation of metabolic control and energy expenditure and thermoregulation, attributes critical for survival. Naturally selected adaptations of thermal tolerance, bipedal posterity, and increased sweat glands assisted in expediting heat loss therein necessitating the immediate transmission of dopamine. Effective persistence hunting relied upon collaborative social interactions for supporting greater group size dependent on the enlarged brains and expanding dopaminergic system.

Sociality and Communication

Increased interpersonal engagement and its subsequent components had the potential to further deepen polyadic bonds and propinquity through other forms of group behaviors including music (Schulkin & Raglan, 2014). Music is not unique to humans, it is well documented throughout a range of animals and is known to be rich with communicative purposes for birds and whales (Lafarga, 2016; Schulkin & Raglan, 2014). It is a binding factor in social bonding for nearly all people, the Deaf/deaf experience it through vibrations, and the hearing experience it by auditory projections (Darrow, 1993; Schmitz et al., 2020); preliminary studies by Sun and Chen (2015) have even shown music promotes consciousness in coma patients. Menon and Levitin (2005) found listening to music facilitates activity within the mesolimbic structure, a central player in reward processing, and instigates autonomic responses in the hypothalamus and other neural systems contributing to the creation and distribution of more dopamine. Music is strongly associated with motivating and inspiring human connections (Dunbar, 2003; Schulkin & Raglan, 2014) through both dopaminergic activities and the elevation of oxytocin (Schulkin & Raglan, 2014). The music therein reflects cognitive abilities and plays a role in reward-seeking behaviors.

The fully upright posture of *H. erectus* meant their nasal and respiratory systems mirrored modern *H. sapiens* anatomical structure more than the anatomy of their predecessor *Homo habilis* (Anton, 2003; Bramble & Lieberman, 2004; Carotenuto et al., 2016; Dezecache & Dunbar, 2012; Hatala et al., 2016; Previc, 1999; Rightmire, 2013). Therein it makes it unreasonable to believe they could not have produced an audible rhythmic beat (Lafarga, 2016). Some scholars believe laughter evolved between 2 and 4 mya (DeLouize et al., 2016; Dezecache & Dunbar, 2012) further supporting *H. erectus* having had the vocal capabilities to elicit sounds. Music has no defined pitch, tone, or melody (Schulkin & Raglan, 2014) and has been observed within the animal kingdom. Due to this, if *H. erectus* partook in the construct of music in group settings their innovative dopaminergic system would have rewarded the behavior building on their desire to repeat the activity.

Briefly, increased sociality strengthened interpersonal relationships and stressed the functions of the growing dopaminergic system. Participation with others through music is one way *H.*

erectus could have formed bonds and bond formation would have positively impacted reproductive success and resultantly their survival.

Critique and Future Directions

The fairly new field of evolutionary cognitive archaeology has been critiqued as being unilinear in thought by Langbroek (2012). Langbroek (2012) views the linear approach to cognitive archaeology as having a superiority complex with modern behaviors valued over both other forms and previous forms of behavior. He has termed it the 'linear ladder model' and believes it is not possible to have a direct line of cognitive evolution when biological evolution is explained through a phylogenetic tree. In contrast, evolutionary cognitive archaeology focuses on primate behavior and thought processes in an attempt to identify characteristic developments of the *Homo* lineage. The discipline does not aim to apply the explanations of cognitive processing between *H. erectus* and *H. sapiens* to another genus or species.

No published counterarguments on the proposal of dopamine aiding in the growth of abilities and enlarged brain size of *H. erectus* have been found.

Dopamine is one of many neurotransmitters that influence physiological and neurological growth and cognition. Further studies on dopamine, neurotransmitters, and hormones need to be completed to fully grasp the role neurological developments had on brain and cranial growth in past hominins.

Conclusion

Cognitive archaeologists believe *H. erectus'* ingenuity in cooking their food had unimaginable repercussions on their bio-physiology and cognitive neurophysiology influencing the genus *Homo* in its entirety. Enhancing the nutrients of their diets through manipulation of fire maximizing the extraction of tyrosine, and consequently, dopamine shortened their intestinal tract, reduced their tooth morphology, and caused larger brains and cranial vaults. Adaptations to bipedalism and the adoption of thermoregulatory properties aided in the introduction of more dopamine, and the rapid expansion of the dopaminergic system gave way to the beginnings of complex social and group behaviors. Reinforcement of and by the dopaminergic system from the incorporation of dopamine from cooked meats complimenting the release of dopamine from physical exertion and their extraversive behaviors played a consequential role in *H. erectus'* unprecedented evolutionary ascent towards the intricate abilities of modern *H. sapiens.*

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