

Evolutionary Perspectives in the Development of the Prefrontal Cortex and its' Applications in the Field of Education

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Abstract

The implications of understanding and applying knowledge related to the PFC are of essence, if the United States is to remain as a nation of scientific progress. Although there is abundant literature referring to rather specific functions and responses to PFC stimuli, more research should be developed to further scrutinize ongoing findings. Understanding the development of the PFC and particularly the disorders associated with this area of the brain has important societal significance. It appears that there is a pattern to disorders associated to the frontal lobes which could explain the development of several illnesses. However, certain questions must be further studied and scrutinized.

Keywords: Prefrontal cortex, executive function, education, evolution, brain

Introduction

The Prefrontal Cortex (PFC) is known to be part of the most recent area in terms of brain evolution. It is also known for been responsible for the executive functions of the brain (Goldberg, 2009). The purpose of this paper is to further discuss the functions and evolutionary perspectives related to the PFC; as well as the effects of dopamine in human behavior. Furthermore, issues related to gender are discussed, as there is clear evidence that certain illnesses affecting the PFC are much more evident in males than in females; such as attention deficit-hyperactivity disorder (ADHD), schizophrenia, and autism (Goldberg, 2009). Considering that the development of the prefrontal cortex has rather important consequences on human behavior, from childhood through early adulthood; implications regarding the educational field are considered (Tamnes et al., 2010).

Executive Function and Evolutionary Perspectives

The PFC is also referred to as the frontal lobes and it embraces 41% of the cerebral cortex. It is responsible for processing decision-making, problem-solving, and initiating-action, among other executive functions which will be further scrutinized. The difference between the human PFC compared to other animals is the capacity to conscientiously anticipate and prepare for challenges; such as in a game of chess, for instance. Because the PFC is interconnected to all functional units of the brain, it operates as the Chief Executive Officer of the brain; quickly locating information for decision-making (Sylwester, 2005). Most of the literature referring to PFC discusses specificities, such as illnesses affecting that specific brain area. Several authors agree that autism, schizophrenia, and ADHD; are some of the conditions that affect the PFC in particular (Couture et al., 2009; Declerck, Boone, & Brabander, 2006; Gilbert et al., 2008; Goldberg, 2009; Hill, 2004; Lenroot & Giedd, 2006; Moreno et al., 2005; Piven et al., 2008; Sylwester, 2005). Nonetheless, some authors actually make a connection between the evolution and adaptation of the brain and the possible development of such illnesses that plague the PFC (Burns, 2007; Crow, 1996; Dietrich, 2004; MacDonald, 2008; Miller & Cohen, 2001).

Executive Function

Executive functions have a prolonged development compared to other cognitive functions and therefore, an array of cognitive abilities evolves sharply in late childhood and at a slower pace in adolescence (Tamnes et al., 2010). The abilities enveloped by the executive function refer to inhibitory control, working memory, planning, strategic thinking, problem-solving skills, goal-orientation, and control (Cerruti & Schlaug, 2008; Declerck, Boone, & Brabander; 2006; Fecteau et al., 2007; Gilbert et al., 2008; Hill, 2004; Koenigs et al., 2007; Miller & Cohen, 2001; Ramachandran, 2011; Shima et al., 2007; Tamnes et al., 2010; Wallis, Anderson, & Miller, 2001). Such conclusions were made possible when researchers realized that patients with injures in the PFC were unable to perform the aforementioned tasks.

In fact, the executive functions of the PFC are also associated with complex verbal skills. A study by Cerruti and Schlaug (2008), was developed to understand the effects of noninvasive transcranial direct current stimulation (tDCS) to the PFC in relation to complex verbal tasks. The researchers found evidence that anodal stimulation to the PFC can improve complex verbal problem-solving tasks (Cerruti & Schlaug, 2008). Because autism, ADHD, schizophrenia, among other disorders, affect communication and social skills; there is a strong relationship between the affected population and dysfunctions of the PFC (Hill, 2004).

According to Ramachandran (2011), individuals with damage in the frontal lobes may appear absolutely normal to anyone; family members are able to detect these individuals' modified behaviors. The common issues related to individuals with damaged frontal lobes are (a) lack of interest in his or her own future; (b) loss of moral compunction, as the individual may laugh at a funeral or urinate in a public place; (c) loss of ambition; (d) loss of empathy; (e) loss of sense of dignity; (f) loss of foresight, and (g) loss of complex personality (Ramachandran, 2011). Some of these attributes can be compared to attributes related to sociopaths, individuals who are highly intoxicated and even animals. Therefore, the frontal lobes are the essence of what it is to be a human being.

Evolutionary Perspectives

In order to make a connection between the developments of certain mental disorders with evolutionary perspectives; a study of the intelligence of the Ashkenazi Jews is associated. The study by Cochran and Harpending (2009) analyzes the provenience of the higher intellectual abilities of the Ashkenazi. The authors support this evidence by arguing that the Ashkenazi's intelligence quotient (IQ) averages 112-115 compared to the European norm of 100. In addition, the Ashkenazim have won more than a quarter of all Nobel science prizes; even though the group represents one-sixth-hundredth of the world's population. Furthermore, the Ashkenazi Jews account for half of the twentieth-century world chess champions, one-fifth of the American CEOs; and 22% of all Ivy League students (Cochran & Harpending, 2009).

According to Cochran and Harpending (2009), the most feasible explanation in regards to the Ashkenazi Jews higher IQ is based on natural selection; for Ashkenazim held white-collar occupations during the middle ages, in Europe. Christians were not allowed to lend money, for the church would accuse them of usury; therefore, such practice was common amongst the Ashkenazim, who eventually became bankers. Such complex mathematical and strategic administration of the lending business has made them successful. Not only trade and finance boosted the intellect of the Ashkenazim, but the Jewish religion supports the idea that Jews must marry within their group. Greater wealth brought the Ashkenazim better eating habits, better shelter, and less risk for dying of diseases. In essence, the "genes that caused increased reproduction gradually become more and more common in a population" (Cochran & Harpending, 2009, p. 189). Conversely, the authors also identified a series of genetic diseases that affect the Ashkenazim up to 100 times more often than other European populations. Diseases such as Tay-Sachs disease, Gaucher's disease, two different forms of breast cancer, and familial dysautonomia; occur in Ashkenazim populations 100 times more frequently (Cochran & Harpending, 2009).

Following Cochran and Harpending's (2009) argumentation that humans are in a continuous evolutionary process are other authors; who suggest that the environment and social demands developed brain structures capable of solving complex information (Crow, 1991; Crow, 1996; Dietrich, 2004; MacDonald, 2008; Miller & Cohen, 2001). Miller and Cohen (2001) argue that animals with less than 100 thousand neurons are capable of searching for food and avoiding predators. Conversely, the human brain supports approximately 100 billion neurons. Such brain capacity allows humans to be more evolved than other animals, but it does present costs as the complexity of the brain functions introduces extensive chances for interference and confusion (Miller & Cohen, 2001). Although MacDonald (2008) and Miller and Cohen (2001) argue that adaptation to rapidly changing environment accounts for brain evolution; Crow (1991) emphasizes on the social environment. Furthermore, Crow (1991) suggests that the brain weight compared to body weight has escalated in much greater proportion than it has ever before. According to the author, such brain escalation has occurred anywhere between five and two million years ago. Natural selection benefited individuals with linguistic skills to deal with the social environment and its demands; thus the enlargement of the brain and development of the PFC (Crow, 1991).

Dopamine. Dopamine is a chemical responsible for motivation and released into the PFC (Declerck et al., 2006; Miller & Cohen, 2001; Tanaka et al., 2007). Dopamine is rather important to the regulation of the executive function, since the executive function includes cognitive process; such as working memory, strategic planning, locus of control, and flexibility of action thought (Declerck et al., 2006; Tanaka et al., 2007).

Because dopamine is released when an individual feels excited about the idea of a reward, this chemical is directly connected to motivation. In this perspective, a student might study rigorously to achieve the highest grade; or an individual will exercise in order to achieve good health. However, dopamine has also negative societal outcomes. Drugs, food, alcohol, sex, gambling, and other addictions have also developed through the individual search for greater release of dopamine, and consequential feelings of euphoria. Some disorders are also connected to a malfunction on the release of dopamine, such as schizophrenia and ADHD; when schizophrenia and Attention Hyperactivity Disorder appears to relate to an overflow of dopamine into the brain and Attention Deficit Disorder appears to relate to low levels of dopamine discharge (Declerck et al., 2006; Miller & Cohen, 2001; Sylwester, 2005; Tanaka et al., 2007).

Issues of Gender and the Prefrontal Cortex

Although Goldberg (2009) discusses several implications related to differences between the female and the male PFCs; only the items referent to the purpose of this paper are discussed. There are certain patterns that appear to be recurrent in the literature regarding the executive functions of the PFC. Because researchers base several findings on the malfunctions of the PFC in order to understand how this region of the brain operates; it was commonly noticed that certain PFC disorders occur in males at much higher rates than in females. Autism, schizophrenia psychosis, Tourette's syndrome, and ADHD; are disorders that affect mostly males (Crow, 1996; Goldberg, 2009; Hill, 2004; Sylwester, 2005).

Some of the aforementioned disorders are not easily perceived early in life and develop later in life, possibly following brain growth. By age five the human brain has reached 90% of its' adult size; however, significant changes in white and gray matter continue into the third decade of life (Lenroot & Giedd, 2006). Furthermore, the male brain is nine percent larger than the female brain; regardless of height and weight (Lenroot & Giedd, 2006). Based on the facts supported by the literature, could it be possible that the ongoing evolution and consequent enlargement of the brain; particularly the already enlarged male brain, developed a range of disorders for growing too much too fast? If the Ashkenazim developed a series of diseases that plague their group in detriment of greater IQ; could it not be that disorders such as ADHD, autism, schizophrenia afflict mainly males for in detriment of enlarged brains? Crow (1996), Goldberg (2009), and Piven (2008) have mentioned enlarged brains in schizophrenic and autistic individuals; however, the authors did not mention that the left and right hemispheres were necessarily symmetric. In addition, it is not uncommon to find individuals with high intelligence among the people affected by the aforementioned disorders. Because schizophrenia, autism, and ADHD are the most common disorder affecting the PFC which are mentioned in the literature; further discussion succeeds.

Autism. According to Sylwester (2005), autistic individuals have difficulties with social interactions and emotional communication; motor and sensory skills can also be affected by the disorder. The condition usually appears in early childhood and affects one in 500 children, 80% of whom are male (Hill, 2004; Sylwester, 2005). Although the majority of the cases appear to affect the cognitive capabilities of autistic individuals, about 10% of autistic children have exceptional capabilities understanding objects and systems in detriment of the lack communication skills (Sylwester, 2005). Researchers found that the social cognition deficits between high functioning autism and schizophrenia are rather similar, which seems to confirm the idea that both disorders afflict the PFC (Couture et al., 2009; Piven, 2008). Because the gifted autistic presents a larger right brain hemisphere and anomalies in the left brain hemisphere; it is suggested that mathematics, music, and the arts are the main interests of these individuals (Sylwester, 2005). Conversely, language and social skills are rather underdeveloped amongst the gifted autistic individuals. Could it be that the accelerated rate in which the right brain grows in autistic males, added to the fact that the male brain is already nine percent larger; explains that this disorder is based on the continuous evolution of the brain? Furthermore, could it explain the reason why males are the target of this disorder in such exacerbated rate?

ADHD. Attention-deficit/hyperactivity disorder (ADHD) is an anomaly that affects the PFC characterized by impulsiveness, lack of focus, and often hyperactivity. It affects individuals during early childhood. Approximately 10% of the population have ADHD and three times as boys present the disorder, compared to girls (Sylwester, 2005). Sylwester (2005) suggests that although ADHD is a great concern amongst educators, for students are incapable to focus on academic work and often disturb the class; there are greater concerns. The author suggests that irregularities in one or more sub-systems that regulate attention can lead to much serious mental illnesses in the future; such as bipolar disorder, schizophrenia, autism, obsessive-compulsive disorder, among other illnesses (Sylwester, 2005). All of the aforementioned illnesses affect the PFC.

Schizophrenia. Schizophrenia is a mental illness that afflicts approximately one percent of the population and develops anytime between late adolescence and early adulthood (Sylwester, 2005). The illness is characterized by delusional, agitated, hallucinatory behavior; or disinterested, irrational, emotionally withdrawn behavior (Sylwester, 2005). Schizophrenia also afflicts more males than females (Goldberg, 2009). Although there is no consensus on this matter, there is a probability that schizophrenia is caused by excess of release of dopamine in the brain; which could explain the agitated hallucinogenic characteristic of schizophrenia (Sylwester, 2005). There is a large number of well-known gifted individuals, or children of gifted individuals; who are or were afflicted by schizophrenia. Among them are Albert Einstein's son—Eduard Einstein; John Forbes Nash, Jr.—Nobel Laureate in economics; Dr. James Watson's son Rufus—Dr. James Watson is co-discover of DNA and Nobel prize winner; Bobby Fischer—world chess champion; David Helfgott—gifted pianist; James Beck Gordon—Grammy award winning musician; and Vaclav Nijinsky—gifted Polish ballet dancer and choreographer. In addition, several gifted chess players are known to have developed schizophrenia (Garbus, 2011). According to Crow (1996), “psychotic illnesses are common and variable in form, but occur in all societies, and are associated with a fertility disadvantage. If, as seems likely, these illnesses are genetic in origin, some explanation for their persistence is called for” (p. 85). In this perspective, if individuals with mental illnesses present a fertility disadvantage; and mental illnesses are present among gifted individuals, is it substantiated evidence that these disorders are an effect of the continuous evolution of the human brain?

Implications in the Educational Field

Educational implications are of substantial importance considering that (a) ADHD and autism affect individuals during early childhood; (b) ADHD could later on develop into schizophrenia; (c) the PFC takes until early adulthood to fully develop; and (d) the executive functions of the brain are fundamental for the academic achievement and societal interactions among the youth. Lenroot and Giedd (2006) imply that the dorsolateral PFC is late in achieving adult levels of cortical thickness. This area is responsible in controlling impulses, judgment, and decision-making. According to the authors, the late maturation of this area of the brain has serious implications related to educational, social, political, and judicial matters; because minors appear not to have reached maturity to qualify for death penalty or to be allowed to drive (Lenroot & Giedd, 2006). The connections between societal domains and the advances in neuroscience are predicted to progress rapidly in the years to come (Lenroot & Giedd, 2006).

Executive Function and Educational Improvement

There are many implications related to executive functions and the youth, which are not necessarily connected to disorders. Take for instance a fictitious scenario in which the social environment of a student demands substantial planning, strategizing, and goal-achieving thoughts. Suppose a student becomes the target of bullies at school. The student elaborates two strategies; strategy A and strategy B. While strategizing, the student predicts the outcomes of each strategy. Under strategy A, the student tells an adult that he is the victim of bullying and his predictions are (a) the bullying will stop and everything will go back to normal; (b) the bullying will continue and become worse, because he talked; (c) the bullying will stop, but he will be rejected in social groups of his peers. Under strategy B, the student decides to remain silent and will not let anyone know he is victim of bullying, therefore he foresees that (a) maybe a new student will arrive and he will be left alone; (b) maybe the bullying will stop soon on its own; or (c) the bullying will become unbearable and he might ask his parents to move to another school. Although this strategy was not included in the initial planning and strategizing initiatives, as bullying becomes unbearable, one of the outcomes could lead to suicide.

All of the planning contemplated by the fictitious student is coordinated through the executive functions of the PFC. The same line of thought is used by children in school daily toward different circumstance; nonetheless, studies specifically related to brain development and student engagement in learning are not so common (Blair, 2002). The importance of understanding the executive functions of the brain and understanding its' development in children is directly linked to the changes of work and society in the United States. The advances in technology, the information-based economy, and the increasing search for individuals who are capable of applying knowledge in diverse ways; are all reasons connected to executive function and educational improvement (Blair, 2002). The role of the United States in the global economy is directly related to the capacity of the educational institutions in fostering (a) enhanced thinking skills, (b) elaboration of strategies, (c) goal setting, (d) self-monitoring or self-control, (e) analytical learning, and (f) metacognitive skills (Blair, 2002).

Parental involvement. The suggestion that the parents have influence in the development and polishing of a child's executive functions is rather axiomatic, considering the level of plasticity of a child's brain. However, Blair (2002) emphasizes the influence of parental personal characteristics on children's effortful control; which supports the idea of substantial levels of plasticity in the child's brain. Blair (2002) suggests that the mother's dependability, self-control, and prudence are noticed by an infant; as well as face-to-face affective synchrony between the infant and the mother. In this perspective, both interactions are connected to the infants' effortful control, as early as age 24 months (Blair, 2002). In this perspective, the early interactions between infant and the mother could predict a greater use of common sense or perhaps the use of reckless behavior later in life.

Decision making. Although an individual's decision making process depends largely upon personality, the thought process can be polished and stimulated at school. According to Goldberg (2009), there are two kinds of decision making. There are *veridical* and *actor-centered adaptive* decision making (Goldberg, 2009). *Veridical* decision making is based on right or wrong. In this perspective, when a student is taking an assessment test, which is mostly based on multiple choice questions; the student is facing right or wrong answers (Caine & Caine, 2006). The lack of individual meaning and personal connection to the student answering the question is not supportive of the cognitive process. Most of the time, homework and assessment tests are based on *veridical* decision making. If a homework question asks the student to name the capital of the state of Georgia; there is not much thinking process involved in the response (Caine & Caine, 2006). It is therefore, a right or wrong answer. Nonetheless, actor-centered adaptive decision making calls for students' life experiences. The type of questions related to *actor-centered adaptive* decision making call for action and perception from the students' (Caine & Caine, 2006; Goldberg, 2009). There is a connection between the scenario established by the question and the student's perception of his own experiences. For instance, if a homework question requests the student's interpretation of a dog and a cat sleeping next to each other. The student will recollect images he has seen in real life, in cartoons and in movies, where dogs chased the cats. He might also recollect he was chased by a dog himself, and the speed the dog was able to reach and so forth (Caine & Caine, 2006). There are several cognitive functions developing and producing elaborate thought when a question is not formulated to respond to right or wrong. The knowledge becomes therefore, applied knowledge rather than floating knowledge. Clearly, schools can become centers of educational improvement where the executive functions of the brain can actually be exercised.

Ethical issues. According to Calabrese and Roberts (2002), one of the most serious issues faced by school districts around the world, is unethical behavior among school administrators. In fact, the misuse of information and financial resources are the most common (Calabrese & Roberts, 2002). The authors mention the manipulation of achievement test scores in Texas; the use of public funds for personal purposes in Kansas; and sexual harassment in New York (Calabrese & Roberts, 2002). Because the educational system is supposed to accommodate, educate, and provide safety to a large number of minors, it is also highly scrutinized when unethical behavior occurs. Nonetheless, if the PFC is responsible for an individual's use of self-control and ethical judgment, what does it say about an adult misusing funds supposed to be applied to the education of children? Is it possible to educate school leaders to make better use of the executive functions of the brain? Are institutions of higher education emphasizing the importance of ethical judgment at the workplace?

Planning Around the Executive Functions of the PFC

It appears that the PFC could originate ambiguous commands in an individual's brain. For instance, suppose a school administrator understands that he or she carries the responsibility to pursue the best interests of the students, and work using ethical behaviors. The use of good judgment and morals is elaborated by the PFC. Conversely, the same school administrator is enthusiastic about purchasing a new sports car. The thought of purchasing and driving the car stimulates the production of dopamine in the brain and clearly produces feelings of happiness and euphoria in the school administrator's brain. In order to buy the car the administrator decides to embezzle school funds. The aforementioned example related to the ambiguity of the functions of the PFC need to be thought to students entering college, or perhaps even as early as high school. When individuals understand the tricks their brains are playing, they might be able to reason with their own thought process. According to Calabrese and Roberts (2002), institutions of higher education need a change in the paradigm of pedagogical applications. One suggested strategy, refers to eliminating fear from the learning individual. If a student is facing a threat, the threat becomes the target of the individual's attention and learning is no longer important. In this perspective, the threat of hunger, lack of shelter, death, among other threats; prevent learning from occurring.

This effect can be clearly seen in country afflicted by war, hunger, and natural disasters. Conversely, countries where individuals feel safe are more likely to have increased rates in academic achievement. Because of that, Calabrese and Roberts (2002) suggest that certain occurrences of unethical behavior are triggered by a person's fear to lose his job; or being embarrassed by the students' low scores on assessment tests. If the individual does not feel threatened, the unethical behavior will not occur. In order to address the unethical behavior triggered by the downpour of dopamine, without the use of drugs, there must be an effort from the schools. From preschool to graduate school, the societal consequences of unethical behavior have to be contemplated by children and adults. The military is a clear example of individual awareness and self-discipline, because the commanders emphasize over and over that if one person makes a mistake, the entire group will be jeopardized (Calabrese & Roberts, 2002). If a kindergartner grows up understanding that her decision to eat all of the frosting of the cake presented all of her classmates from eating the cake, creating an environment of anger and sadness from her friends; perhaps she will not grow up to be the next Bernard Madoff.

Conclusion

The implications of understanding and applying knowledge related to the PFC are of essence, if the United States is to remain as a nation of scientific progress. Although there is abundant literature referring to rather specific functions and responses to PFC stimuli, more research should be developed to further scrutinize ongoing findings. Understanding the development of the PFC and particularly the disorders associated with this area of the brain has important societal significance. It appears that there is a pattern to disorders associated to the frontal lobes which could explain the development of several illnesses. However, certain questions must be further studied and scrutinized. Why males are more prone to carrying PFC disorders than females? Does it have anything to do with brain size, since the male brain is larger? Does it have anything to do with the continuous growth of the human brain, based on evolutionary observation? The response to these questions is important because the cause or cure for autism, for instance, is not yet discovered and some parents are advocating against the vaccination of children. Some parents believe that the vaccines are the cause of their children's autism. Today, children in the United States receive vaccination to 15 types of illnesses; such as (a) hepatitis A; (b) hepatitis B; (c) diphtheria; (d) tetanus; (e) polio; (f) measles; (g) mumps; (h) rubella; (i) varicella; among others. Some of these diseases are highly contagious. The reason why the United States has such high rate of survival among children is clearly for its' effective use of medical research and vaccination.

Furthermore, the educational implications of the lack of association among academic fields are detrimental to society, as well. There is a deficiency in the literature referring to interdisciplinary studies focused on the functions of the PFC and education. The current knowledge of the executive functions is not being used to improve student achievement in school, because the school leaders have no information about it. Therefore, the mechanics of the PFC must be exposed to students in higher education so this knowledge may be utilized within the schools. The ability to strategize, plan, execute, and control can be learned in school. Take for instance, Alexander *the Great* who ruled the kingdom of Macedonia during the 300s BC. Alexander was able to conquer one of the largest empires in history (Williams, 2007). The reason for his success as a battlefield strategist was his early training. Alexander was trained by his father king Philip II in the art of battling and by Aristotle in philosophy and thinking skills (Williams, 2007). Between approximately 31 BC and AD 14 Emperor Augustus was one of the most prominent leaders in history. Augustus was able to strategize, plan, and conquer the fidelity of the Roman citizens and remain in power longer than most emperors. Augustus learned his skills from his great uncle Julius Caesar (Williams, 2007). An individual will thus, adopt the skills which are nurtured since early in life.

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