

Drugs of our brain

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Abstract

Neurotransmitters, neuromodulators and neurohormones can be considered as one interconnected system, responsible for producing “the drugs of our brain”. In this paper, we will review their effect on human cognition and behavior, focusing mainly on dopamine, serotonin, and testosterone. We will summarize these findings by presenting some of the personality theories based on neuromodulation.

Main keywords: neurotransmitters, neuromodulation, dopamine, serotonin, testosterone, behavior, cognition, personality

1 THE BIOLOGY BEHIND NEUROMODULATION

Human nervous system consists of 10^{11} – 10^{12} neurons. Due to complex biochemical processes that occur in our brains, neurons can communicate with each other by continuously sending and receiving signals from one another. Molecules that allow communication between neurons are known as neurotransmitters. (Beňušková, 2002)

Shortly after their release, neurotransmitters are inactivated by specific enzymes or by re-uptake mechanisms. However, the main interest of this paper will be in neuroactive substances known as neuromodulators. Neuromodulators can be considered as a type of neurotransmitters that are not reabsorbed by the pre-synaptic neuron or broken down by enzymes and therefore have a prolonged duration, which in turn has modulatory function on postsynaptic events. (Von Bolhen und Halbach & Dermietzel, 2006)

Neuromodulators, such as dopamine, serotonin, acetylcholine, and many others, therefore modify the effect of neurotransmitters. As Cohen and Aston-Jones (2005) pointed out, these systems are involved in almost every mental function, starting from attention, memory, and learning, to emotions. Furthermore, they can influence behavior and, according to recent research, even more stable responses to the environment stimuli, such as personality. Personality neuroscience is an emerging field that focuses on understanding the sources of personality in the brain and, by doing so, explain the individual differences in behavior and cognition (DeYoung & Gray, 2009).

It is well known that overly reduced or increased activity of neurotransmitter systems can lead to different kinds of neurological and psychiatric disorders, from Alzheimer’s disease and addiction, to depression, schizophrenia, and many others (Beňušková, 2002). However, the main focus of this paper will be on how these neuroactive substances – metaphorically speaking, “drugs” – affect our cognition and behavior on a daily basis, and whether we can make assumptions about human

personality traits based on the differences in these processes. We will also take in consideration neurohormones, as additional important factors in these processes.

In the next section, we will briefly present some of the neuromodulators and neurohormones that inspired the most research in this field and their core functions in human brain.

2 DOPAMINE, SEROTONIN, AND TESTOSTERONE

Dopamine has long been associated with the processing of rewarding stimuli and plays an important role when it comes to reinforcement learning. Dopaminergic neurons in ventral tegmental area and substantia nigra are connected to the brain structures involved in motivation and goal-directed behavior. Research has shown that these neurons have a predictive role when it comes to environmental events, by emitting positive or negative signal depending on whether the event is better or worse than predicted (e.g. Schultz et al. 1997) and help us react properly to the changes in the environment (Venton & Wightman, 2003). In addition, there is evidence that acetylcholine and noradrenaline levels influence our decision-making in the face of uncertainty (see Cohen & Aston-Jones, 2005; Yu & Dayan, 2005). Zehentbauer (2012) goes far as comparing dopamine to hallucinogen drugs, claiming that it awakes our fantasy and creativity.

Serotonin is probably most famous for having antidepressant effects, however it also plays an important role in social behavior involving aggression and anxiety, along with appetite, sexual behavior, pain sensitivity and learning (Lucki, 1998). Studies have found evidence on further serotonin effects on memory consolidation, attention, and cognitive flexibility (Schmitt et al. 2006). Experiments with serotonin showed its effect on performance in cognitive tests involving emotionally salient rewards and feedback, suggesting that it's involved in affective aspects of impulsivity as well (Chamberlain et al. 2006).

Testosterone is a steroid sex hormone, mainly responsible for our physical maturation. However, extensive research indicates a link between testosterone levels and our cognitive abilities and behavior (Durdiakova, Ostatnikova & Celec, 2011). Today it is well known that testosterone has an important role in social interactions in both sexes. It has even been associated with a more dominant, aggressive, and egoistic behavior. However, one study questioned the difference between people's prejudice and the actual effect of testosterone on human behavior. Eisenegger et al. (2010) have found that a single dose of testosterone in women *increased* the fair bargaining behavior, therefore reducing conflicts and improving social interactions, although women that received a placebo acted much more unfairly than the control group. Another study showed that subjects with higher level of testosterone expressed greater risk-taking behavior than low-testosterone participants (Stanton et al. 2011). Durdiakova et al. (2011) have provided a summary of the main effects of testosterone on human mind: generally, high levels of testosterone increase our spatial orientation and mental rotation skills, lower verbal abilities and modulate the mood and behavior by increasing aggression and decreasing anxiety and depression.

Although these numerous effects may seem difficult to grasp, they have inspired a great number of research in the field of personality neuroscience. We will outline some of the recent personality theories that are based on neuroscience.

3 ROLE OF NEUROMODULATORS IN PERSONALITY

According to DeYoung (2013), dopamine has various effects on personality in terms of traits that are connected to the process of exploration. He understands exploration as “any behavior or cognition motivated by the incentive reward value of uncertainty.” (DeYoung, 2013, p. 1) He suggested a model summarizing these effects on personality, focusing mainly on the NEO Personality Inventory (see Costa & McCrae, 1992), also known as the Big Five, one of the most widely used methods for personality assessment in psychology. His theory hypothesizes primary positive influence of dopamine on a wide range of traits, such as extraversion, assertiveness, openness, creativity, sensation seeking and others.

A rather different approach is the one of Zehentbauer (2012). Due to his vast experience in medicine in addition to practice in psychotherapy, he has proposed a human typology based on the seven most dominant neurotransmitters: adrenalin, noradrenalin, serotonin, endorphin, oxytocin, acetylcholine, and dopamine. For example, the adrenaline type has extremely active, sometimes even aggressive behavior, while the dopamine type people are rich in fantasy with “a lot of crazy ideas” and oxytocin dominated individuals tend to enjoy life more and are rather “sexy” (for full typology see Zehentbauer, 2012, p. 70). Though his descriptions seem as plausible as some zodiac signs characterization in a tabloid, they are based on some general beliefs about the main functions of neurotransmitters. However, they haven’t been scientifically validated.

Yet another approach has emerged after series of studies on romantic love and partner compatibility. Fisher and her team have identified four temperament dimensions that, based on their findings, have neural correlates in our brains (Brown, Acevedo & Fisher, 2013). They have developed a Fisher Temperament Inventory (FTI) questionnaire, which measures following dimensions: Curious/Energetic, Cautious/Social Norm Compliant, Analytical/Tough-minded, and Prosocial/Empathetic. Based on fMRI studies that elicited feelings of romantic love, these dimensions have been associated with corresponding neural systems: dopamine, serotonin, testosterone, and estrogen/oxytocin system (Brown et al. 2013). A recent study conducted by Fisher et al. (2015), has also shown correlations of FTI scales with the three dimensions of the Big Five inventory: openness to new experience, agreeableness, and conscientiousness. The authors have concluded that the FTI is the first personality measure coming directly from neuroscience, using neuromodulator systems and tested by fMRI studies. However, we should be careful when making general assumptions, since the studies mentioned above were focused on people when having elicited feelings of romantic love. Therefore, *when in love*, people can be classified as belonging to these four temperament dimensions based on neural correlates.

As we approach the end of this paper, the key question arises – what are the implications of these numerous findings and how could we use them in our daily lives? Helen Fisher certainly recommends us to rely on it while looking for a lifetime partner. However, Zehentbauer (2012) suggests that we can learn how to control these neuromodulators with changes in our diet and exercise, and by doing so, enhance our cognitive abilities to lead a happier life. So, the next time you’re feeling blue, go for a jog, meditate, or simply laugh – the drugs of your brain will take care of the rest.

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