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Dopaminergic pathway and athletic mind

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Abstract

Purpose: we reviewed that the mental fatigue is influenced by dopamine depletion, and we assume that increasing DA level can increase athletic stamina and promote athletic performance after prolong exercise.

Methods: The search strategy was according to key words contain, Mental fatigue , Decision making , Dopamine, Stroboscope training through the Google scholar, PubMed, and Elsevier. Among the literatures, 100 papers include review and original articles were studied. Finally, we decided to select 49 papers based on similarity and recent studies so more than 50 percent of papers were excluded, because of they were out of date or irrelevant to key words.

Results: Based on many studies, it was found dopamine has an essential role on athletic performance and his stamina.

Conclusion: The stroboscope vision training in sports could enhance the dopaminergic neurons and associated visuo-motor skills.

Key words: *Dopamine, dopaminergic projection, mental fatigue, decision making*

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Introduction

The history of research on Dopamine (DA) levels is often referred to the Carlson researches. In that time investigations were started about antipsychotic drugs such as Chlorpromazine after second war. This drug was used on second war for decreasing hallucination and internal voice was that were made because of war affections.[1] Dopamine (DA) is an important catecholamine neurotransmitter that has a key role in cognitive functions, such as motivation , reward and motor functions.[213] This role is mediator by three main pathways that is described later. In fact any changes in dopamine levels can cause some diseases such as Parkinson's disease (PA) which is correlated to decrease Dopamine level.[456] Dopamine is produced mainly in the Substantia Nigra pars compacta and Ventral tegmental area.[7] Dopamine has outstanding role in movement, cognition and learning.[2] To sustain this first we briefly review dopamine structure, dopaminergic pathway, and its role in mental fatigue and sport.

Dopamine structure and its Role

Studies that were done after second world war and other investigations were done on brain's antipsychotic receptor had result in finding out D2 receptor location.[89] Dopaminergic neurons in the substantia nigra, ventral tegmental area (VTA) and the arcuate nucleus of the hypothalamus are centers for producing Dopamine .[10111] D1 like family and D2 like family are two main receptors of Dopamine . .[1091213] .D1 receptors are the most abundant in the Prefrontal cortex (PFC) of brain than D2 receptors, while D2 receptors are more prevalent in the striatum than in the cortex. D1 receptors have an inhibitory or excitatory role in a variety of CNS functions, including working memory, attention,[9] motor control , decision making, regulate growth and development, regulations of feeding, affect, attentions, reward, sleep, impulse control, reproductive behaviors , and learning.[9141516] D2

receptors family are expressed in striatum, ventral tegmental area (VTA) and nucleus accumbens and olfactory bulb. [1091718] D2 receptors functions in the brain are almost inhibitory and modulate mood, emotional stability in the limbic system and movement control in the basal ganglia.[10 19]

Sometimes stimulation of Dopamine receptors such as D2 in some in mesolimbic areas causes emerging of positive sign of Schizophrenia ,for example, Delusion and hallucination which are seen in individuals who taking Antipsychotic drug, for instance in the people who taking Amphetamine and chlorpromazine that causes increase Dopamine(DA) level in CNS[16202211].

Dopamine's role on the brain

Most of Dopaminergic cells are located in the midbrain in three groups: the retro bulbar, the substantia nigra (SN) and the ventral tegmental area (VTA). Three major pathways made dopaminergic circuit system nigrostriatal, mesolimbic/mesocortical and tubularinfundibular pathway.[2110]Nigrostriatal pathway that originate from the pars compacta of SubstantiaNigra (SN) and end to striatum dopamine plays an crucial role in execution motor and learning new motor skills. This pathway could be affected by Parkinson disease.[2223102425] some other dopaminergic neuron are positioned in VTA and their axons project to Limbic system , Nucleus Accumbens , bed nucleus of stria terminalis (BNST), and frontal cortex. These pathway is involved with reinforcement, motivation, mood and thought also it is related to pleasurable activity such as occupation , sex and food or using drug.[10 242627] The Mesocortical Pathway that dopaminergic fibers originate from the ventral tegmental area(VTA) and terminate to the frontal cortex that include the orbitofrontal cortex (OFC) and anterior cingulate[10 262829] . Mesocortical mediates cognitive

attitude such as working memory, attention and also mediate emotional.[30]

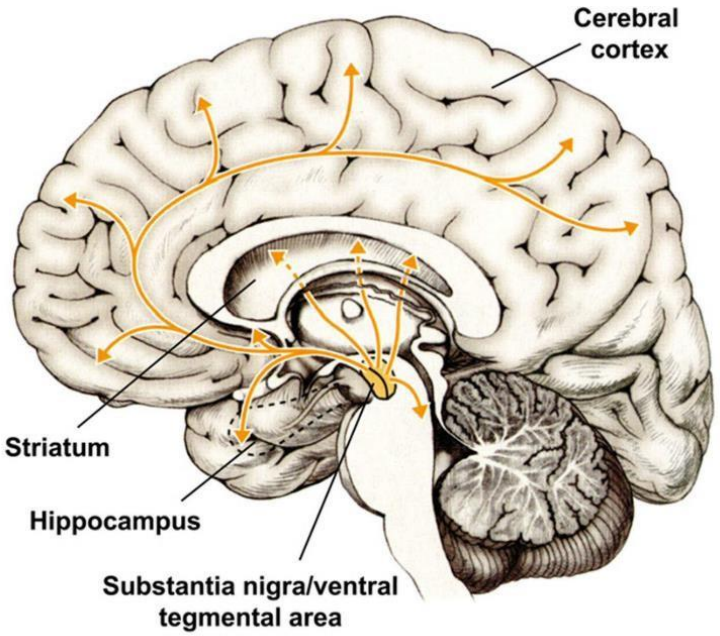

Figure 1-1 Dopaminergic pathway througout the brain.[31]

Basal ganglia

The basal ganglia are a group of subcortical structures involved in the integration and processing of sensorimotor, cognitive and limbic information.[32] The Caudate nucleus is a large structure in the basal ganglia and together with the putamen, is called the striatum or the dorsal striatum.[33]

Dysfunction of these nuclei results in a wide variety of motor neurological disorders, including Parkinson's disease, Huntington's disease, dystonia, hemiballism and Tourette's syndrome.[34] The striatum is a central component of the basal ganglia that collects and processes information coming from the cerebral cortex and the thalamus.[35]

Behavior and motor system is the objective output of the nervous system, whether in cognition or action. [3637] Nervous systems are equipped with several motor programs that are acquired genetically such as locomotion, posture, breathing, eye movements, feeding, chewing, swallowing, bowel and bladder functions, and reproductive motor behaviors, eye-head orienting, and vocalization that are controlled by the brain stem motor centers or spinal cord. [1038] Complex behavioral tasks usually necessitate activation of caudate nucleus neurons. [33]

More than 90% of the striatal neurons are medium spiny neurons MSNs (also known as Golgi type I cells) which have a long axon, medium-sized cell body and spiny dendrite and the remainder are mostly cholinergic and GABAergic interneurons that are morphologically distinguished by a large soma and wide dendritic arborisation.[39 40 37] MSNs receive excitatory glutamatergic inputs from the cerebral cortex and the thalamus onto the tips of the dendritic spines, and a modulatory dopaminergic inputs from the midbrain.[35] The striatal medium spiny output neurons are also inhibitory (GABAergic) that project to the substantia nigra pars reticulata, Globus pallidus pars interna , and ventral pallidum [3740]. In the striatum both D1 (excitatory) and D2 (inhibitory) receptors are found. The major role of these two receptors in the striatum is to control and initiation of motor plans[941].

DA modulation of incoming transmission to the striatum plays a key role in the functional expression of reward-seeking behaviors and motor control [27]. In all animals the striatum have a fundamental role in motor activity , dorso-medial and dorso-lateral areas are predominantly involved in motor control, while ventro-medial segments are mostly involved in the expression of reward processing, motivation and salience[427] . But most neuroscientists tacitly assume that the cerebral cortex is responsible for the initiation of any goal-directed

behavior[26].The parts of cortex is related to this behavior of the goaldirected system is including the dorsal posterior parietal and large parts of the frontal cortex .[18]

Mental Fatigue

Mental Fatigue is an event that occur for most people in their life and manifest by reduced cognitive performance and is effortful to achieve a specific goal.[43] . There many factor that can cause mental fatigue, for example lack of energy, being unmotivated and changes in perception and mood. Mental fatigue can cause in effortful perceive, and has been found to activate the cortical regions involved in athletes' inhibition system[44]

Decision making

Decision making is a process too choose a selection among options. Some processes are contained in decision making such as seeking information and comparison between options. [45]In adaptation to uncertainty situation decision making has outstanding role .[46] Even for being successful in game playing for instance in football or handball decision making is an important element. [47] Neuroimaging studies depict that decision making function is on prefrontal cortex.[48] Median prefrontal cortex draw on evaluating judgment such as ventromedial prefrontal cortex is which engaged more in learning, processing expectation and outcome prediction, while the dorsomedial prefrontal cortex evaluate the differences between factual and predicted result. [46]

Dopamine and Exercise

Prolong exercise can increase Extracellular DA concentration in brain during exercise , but in some in animal research depict that after

prolong exercise and exhausted DA can being decreased in brain . It suggest that after extreme exercise and stress can deplete Tyrosine precursor of DA and decrease DA level in brain subsequently. [49] Dobryakova et al. suggested in their article that dopamine is involved not only in effort–reward calculation but might also contribute to fatigability of cognitive processes.[43]

Concluding remarks

As mentioned before dopaminergic activity of brain specially D2 receptors in prefrontal cortex has correlation with motivation, feeling arousal and reward. In the football or other sport that consume most of energy of athletic , it could have effect on athletics to suffer from mental fatigue. To promote athletic performance by manipulating individual's intrinsic motivation, rewards system, or increasing brain DA concentration ,it should be evaluate their decision making score by Iowa gambling task and then try increase feeling of competence that influence intrinsic motivation , consuming Tyrosine supplementation to compensate depletion of dopamine precursor or even using Shutter glasses to increase value of brain dopamine to improve their decision making system in mental fatigue duration .

References

1. Syslova K, Rambousek L, Bubenikova-Valesova V, Slamberova R, Novotny P, Kacer P. Dopamine Analysis in Neuroscience Research. *Dopamine Funct Regul Heal Eff*. 2012;(December 2015):81-112.
2. Braver TS, Cohen JD. Dopamine, cognitive control, and schizophrenia: the gating model. 1999;121(2):327-349. doi:10.1016/s00796123(08)63082-4
3. Juárez Olguín H, Calderón Guzmán D, Hernández García E, Barragán Mejía G. The role of dopamine and its dysfunction as a consequence of oxidative stress. *Oxid Med Cell Longev*. 2016;2016. doi:10.1155/2016/9730467
4. Strange PG. Dopamine Receptors Review. 2008;(Table 2):1-8. http://www.komabiotech.co.kr/pdf/dopamine_receptors_review.pdf.
5. Luo SX, Huang EJ. Dopaminergic neurons and brain reward pathways: From neurogenesis to circuit assembly. *Am J Pathol*. 2016;186(3):478-488. doi:10.1016/j.ajpath.2015.09.023
6. Yeragani VK, Tancer M, Chokka P, Baker GB. Arvid Carlsson , and the story of dopamine. 2010;52(1):87-89. doi:10.4103/0019-5545.58907
7. Cachope R, Cheer JF. Local control of striatal dopamine release. *Front Behav Neurosci*. 2014;8(May):1-7. doi:10.3389/fnbeh.2014.00188
8. Seeman P. The Dopamine Receptors. *Dopamine Recept*. 2013;(December 2009). doi:10.1007/978-1-4757-2635-0
9. Marsden CA. Dopamine: The rewarding years. *Br J Pharmacol*. 2006;147(SUPPL. 1):136-144. doi:10.1038/sj.bjp.0706473
10. Ayano G. Dopamine: Receptors, Functions, Synthesis, Pathways, Locations and Mental Disorders: Review of Literatures. *J Ment Disord Treat*. 2016;2(2):2-5. doi:10.4172/2471-271x.1000120
11. Volkow ND, Fowler JS, Gatley SJ, et al. PET evaluation of the dopamine system of the human brain. *J Nucl Med*. 1996;37(7):1242-1256. http://www.ncbi.nlm.nih.gov/pubmed/8965206.

12. Takahashi H, Yamada M, Suhara T. Functional significance of central D1 receptors in cognition: Beyond working memory. *J Cereb Blood Flow Metab*. 2012;32(7):1248-1258. doi:10.1038/jcbfm.2011.194
13. Missale C, Russel Nash S, Robinson SW, Jaber M, Caron MG. Dopamine receptors: From structure to function. *Physiol Rev*. 1998;78(1):189-225. doi:10.1152/physrev.1998.78.1.189
14. Sang-Min Lee, Yang Yang and RBM. Dopamine D1 Receptor Signaling: Does GaQ–Phospholipase C Actually Play a Role? *TTHE J Pharmacol Exp Ther*. 2014;20(16):RC91-RC91. doi:10.1523/jneurosci.20-16j0001.2000
15. Nichols DE. Dopamine Receptor Subtype-Selective Drugs:D1-Like Receptors. *Dopamine Recept*. 2013:75-99. doi:10.1007/978-1-47572635-0
16. Howes OD, Kapur S. The dopamine hypothesis of schizophrenia: Version III - The final common pathway. *Schizophr Bull*. 2009;35(3):549-562. doi:10.1093/schbul/sbp006
17. Souza UMD. The Dopamine Receptors. *Gene Promot Struct Dopamine Recept*. 2013:23-46. doi:10.1007/978-1-4757-2635-0
18. van de Groep IH, de Haas LM, Schutte I, Bijleveld E. Spontaneous eye blink rate (EBR) predicts poor performance in high-stakes situations. *Int J Psychophysiol*. 2017;119:50-57. doi:10.1016/j.ijpsycho.2017.01.009
19. Valenzuela CF, Puglia MP, Zucca S. Focus on: Neurotransmitter systems. *Alcohol Res Heal*. 2011;34(1):106-120.
20. Yasunori Oda 1 NK 2, Masaomi Iyo. Alterations of Dopamine D2 Receptors and Related Receptor-Interacting Proteins in Schizophrenia: The Pivotal Position of Dopamine Supersensitivity Psychosis in Treatment-Resistant Schizophrenia. *Int J Mol Sci*. 2015;16(12):30144-30163. doi:10.3390/ijms161226228
21. Sescousse G, Ligneul R, van Holst RJ, et al. Spontaneous eye blink rate and dopamine synthesis capacity: preliminary evidence for an absence of positive correlation. *Eur J Neurosci*. 2018;47(9):1081-1086. doi:10.1111/ejn.13895
22. Fuxe K, Manger P, Genedani S, Agnati L. The nigrostriatal DA pathway and Parkinson's disease. *Park Dis Relat Disord*. 2006:71-83. doi:10.1007/978-3-211-45295-0_13
23. Railo H, Olkoniemi H, Eeronheimo E, Pääkkönen O, Joutsa J. Dopamine and eye movement control in Parkinson ' s disease : deficits in corollary discharge signals ? 2018:1-37.

24. Grace AA, Lodge DJ, Buffalari DM. Dopamine-CNS pathways and neurophysiology. *Encycl Neurosci*. 2010:549-555. doi:10.1016/B978008045046-9.01140-2
25. Caminiti SP, Presotto L, Baroncini D, et al. Axonal damage and loss of connectivity in nigrostriatal and mesolimbic dopamine pathways in early Parkinson's disease. *NeuroImage Clin*. 2017;14(October 2016):734-740. doi:10.1016/j.nicl.2017.03.011
26. Adinoff B. Neurobiologic processes in drug reward and addiction. *Harv Rev Psychiatry*. 2004;12(6):305-320. doi:10.1080/10673220490910844
27. Trainor BC. Stress responses and the mesolimbic dopamine system: Social contexts and sex differences. *Horm Behav*. 2011;60(5):457-469. doi:10.1016/j.yhbeh.2011.08.013
28. Ikegami A, Duvauchelle CL. Dopamine Mechanisms and Cocaine Reward. *Int Rev Neurobiol*. 2004;62:45-94. doi:10.1016/S00747742(04)62002-2
29. Lapish CC, Seamans JK. The ability of the mesocortical dopamine system to operate in distinct temporal modes. 2017;191(3):609-625. doi:10.1007/s00213-006-0527-8.The
30. Floresco SB, Magyar O. Mesocortical dopamine modulation of executive functions: Beyond working memory. *Psychopharmacology (Berl)*. 2006;188(4):567-585. doi:10.1007/s00213-006-0404-5
31. Dobryakova E, Genova HM, DeLuca J, Wylie GR. The dopamine imbalance hypothesis of fatigue in multiple sclerosis and other neurological disorders. *Front Neurol*. 2015;6(MAR):1-8. doi:10.3389/fneur.2015.00052
32. Graybiel AM, Grafton ST. The striatum: Where skills and habits meet. *Cold Spring Harb Perspect Biol*. 2015;7(8):1-13. doi:10.1101/cshperspect.a021691
33. Hikosaka O. Basal ganglia mechanisms of reward-oriented eye movement. *Ann N Y Acad Sci*. 2007;1104:229-249. doi:10.1196/annals.1390.012
34. Adriana Galvan1, 2, Masaaki Kuwajima1,+, and Yoland Smith1 2, 1Yerkes National Primate Research Center, Emory University, Atlanta, Georgia 30322 U, 2Department of Neurology, Emory University, Atlanta, Georgia 30322 UsaR. Glutamate and GABA receptors and transporters in the basal ganglia: What does their subsynaptic localization reveal about their function? *Neuroscience*. 2006;143(2):351–375. doi:10.1038/mp.2011.182.doi

35. Matamales M, Bertran-Gonzalez J, Salomon L, et al. Striatal mediumsized spiny neurons: Identification by nuclear staining and study of neuronal subpopulations in BAC transgenic mice. *PLoS One*. 2009;4(3). doi:10.1371/journal.pone.0004770
36. Alexxai V. Kravitz1 and Anatol C. Kreitzer1 2. Striatal Mechanisms Underlying Movement, Reinforcement, and Punishment. 2012;27(3):1201-1210. doi:10.1152/physiol.00004.2012.Striatal
37. Grillner S, Hellgren J, Ménard A, Saitoh K, Wikström MA. Mechanisms for selection of basic motor programs - Roles for the striatum and pallidum. *Trends Neurosci*. 2005;28(7):364-370. doi:10.1016/j.tins.2005.05.004
38. Hikosaka O, Takikawa Y, Kawagoe R. Role of the basal ganglia in the control of purposive saccadic eye movements. *Physiol Rev*. 2000;80(3):953-978. doi:10.1152/physrev.2000.80.3.953
39. Rikani AA, Choudhry Z, Choudhry AM, et al. The mechanism of degeeeration of striatal neuronal subtypes in Huntington disease. *Ann Neurosci*. 2014;21(3):112-114. doi:10.5214/ans.0972.7531.210308
40. ROTHWELL JC. the Motor Functions of the Basal Ganglia. *J Integr Neurosci*. 2011;10(03):303-315. doi:10.1142/s0219635211002798
41. Gagnon D, Petryszyn S, Sanchez MG, et al. Striatal Neurons Expressing D1 and D2 Receptors are Morphologically Distinct and Differently Affected by Dopamine Denervation in Mice. *Sci Rep*. 2017;7(January):9-17. doi:10.1038/srep41432
42. Liljeholm M, O 'doherty JP. Contributions of the striatum to learning, motivation, and performance: an associative account Anatomical and functional delineations of the striatum. *Trends Cogn Sci*.
43. Dobryakova E, Deluca J, Genova HM, Wylie GR. Neural correlates of cognitive fatigue: Cortico-Striatal circuitry and effort-reward imbalance. *J Int Neuropsychol Soc*. 2013;19(8):849-853. doi:10.1017/S1355617713000684
44. Schiphof-Godart L, Roelands B, Hettinga FJ. Drive in sports: How mental fatigue affects endurance performance. *Front Psychol*. 2018;9(AUG). doi:10.3389/fpsyg.2018.01383
45. Jin M, Ji L, Peng H. The relationship between cognitive abilities and the decision-making process: The moderating role of self-relevance. *Front Psychol*. 2019;10(AUG):1-13. doi:10.3389/fpsyg.2019.01892
46. Collins A, Koechlin E. Reasoning, learning, and creativity: Frontal lobe function and human decision-making. *PLoS Biol*. 2012;10(3). doi:10.1371/journal.pbio.1001293

47. Kaya A. Decision Making by Coaches and Athletes in Sport. *Procedia - Soc Behav Sci*. 2014;152:333-338. doi:10.1016/j.sbspro.2014.09.205
48. Volz KG, Schubotz RI, Von Cramon DY. Decision-making and the frontal lobes. *Curr Opin Neurol*. 2006;19(4):401-406. doi:10.1097/01.wco.0000236621.83872.71
49. Phil Watson P| D of HP| VUBB. TYROSINE SUPPLEMENTATION : CAN THIS AMINO ACID BOOST BRAIN DOPAMINE AND IMPROVE PHYSICAL AND MENTAL PERFORMANCE ? 2016;28(157):1-6.