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What happens in the top athletes mind? a review study

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ABSTRACT

During last decades by inception of Neuroscience and increasing experimental researches on catecholamine neurotransmission, the importance of Dopamine has been raised more than past. Dopamine is a crucial neurotransmitter with precursors (biosynthesis) –tyrosine, L-DOPA that is implicated in many neuropsychological disorders. Dopamine functions are also has engaged into body movement and as well it has role in eye movements. Dopamine also has role on cognitive and enhance the visuo-motor tasks such as playing baseball game via training by strobospectacle. Therefore, in this article we explain its role and its architecture (i.e. receptors, basal ganglia and striatum and their pathways). , and its role upon influencing saccade and persuit eye movements. Finally we try to answer the main question how do strobotraining affect brain dopamine levels and coordination of athletes' movements?

Keywords: *Dopamine, Saccade, Stroboscope Training, Visuo-Motor Skill*

1. INTRODUCTION

It is found out that Dopamine as well neurotransmitter role in the brain is precursor of norepinephrine. The highest regional concentration of Dopamine is in the Basal ganglia that has a main role in movement.[1] The dynamic aspects of sports is strongly depends on visual processing. Most athletes exercise to improve their power and understanding of the game but this is not sufficient to gain a competitive edge. It needs training of vision and attention.[2] It has been found out vision training with shutter glasses (strobotraing) during exercising greatly enhances stamina of the human visual system[345678] . From a neuroscientist perspective Dopamine has a crucial role for movement, cognition and learning by its individual receptors.[9] To sustain this first we briefly review this neurotransmitter, built from tyrosine and a precursor of norepinephrine. Dopamine produces mainly in the Substantia Nigra pars compacta and Ventral tegmental area in mid brain and conveys through three pathways to striatum, limbic and cortex. It should be noted dopamine plays the different rols via specific receptors (D1 likes and D2 likes families).

Dopamine architecture and its role

Dopamine (DA) is one of the most important catecholamine neurotransmitter that has a crucial role in cognitive functions, such as motivation, reward, decision making as well as motor functions.[91011] These roles are mediated by three principal pathways that are include : **Nigrostriatal pathway , Mesolimbic dopaminergic pathway, and mesocortical pathway**.[12131415]

In **Nigrostriatal pathway** the projection of Dopaminergic neurons in pars compacta of SubstantiaNigra (SN) and go through medial forebrain bundle to the caudate nucleus and the putamen that are called striatum[151617]. Striatum has reciprocal pathway with supplementary motor area and dopamine can has effect on initiation and execution of movements and learning new motor skills. [1819] Whilst in **Mesolimbic dopaminergic pathway** axons of dopaminergic neurons are originated from VTA in midbrain and then project to Hypothalamus , and limbic system . These pathway has a key role in reinforcement, motivation, mood and thinking also it is related to pleasurable activity such as occupation, sex and food or using drug.[15 162021]. The third dopaminergic pathway is Mesocortical pathway . Dopaminergic fibers originate from the ventral tegmental area(VTA) and go rostrally to the frontal lobe that include the orbitofrontal cortex (OFC) [15 202223] . [16,44,46,47]. Mesocortical dopamine has influence on D1 receptors in prefrontal cortex(PFC) and also mediates cognitive attitude such as working memory, attention, and emotional. [24] So any delicate change in mesocortical pathway dopamine level can causes symptoms of schizophrenia[25 15 25] .

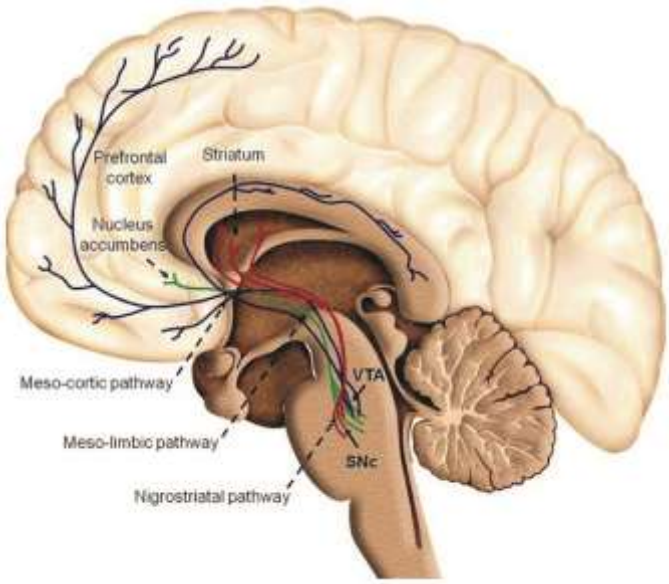

Figure 1[26] Efferent pathways of the dopaminergic system. The nigrostriatal pathway , The mesolimbic pathway, and the neocortical pathway connects

Investigation on antipsycotic drug like Chlorpromazine after second world war because of hallucination and internal voice as caused to explore role of dopamine receptor location. .[102728] As mentioned before , dopamine is produced in the dopaminergic neurons which in the substantia nigra, ventral tegmental area (VTA) and the arcuate nucleus of the hypothalamus.[151029] D1 and D2 like family are two main groups of Dopamine receptors. D1 Like family comprise its subgroup D1 and D5 which are postsynaptic and are found in high concentration in substantia nigra, olfactory bulb, nucleus accumbens, and striatum .[15283031] . In the PFC of brain, D1 receptors are the most abundant than D2 receptors, while D2 receptors are more in the striatum than in the cortex. D1 receptors have role in a variety of CNS functions, including working memory, attention,[28] motor control , decision making, regulate growth and development, regulations of feeding, affect, attentions, reward, sleep, impulse control, reproductive behaviors, learning.[28323334] D2 receptors family are pre and post-synaptic and are highly expressed in striatum, ventral tegmental area (VTA) and nucleus accumbens and olfactory bulb. [15283536] 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.[15 37]

Sometimes so incitement of Dopamine receptor 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. For this reason in treatment of Schizophrenia, D2 receptors on cholinergic interneurons are the target for blocking that causes extrapyramidal signs.[343891410].

The basal ganglia are a group of subcortical structures involved in the integration and processing of sensorimotor, cognition and processing of limbic information. Dysfunction of these nuclei results in a wide variety of motor neuron diseases, including Parkinson's disease, Huntington's disease, dystonia, hemiballism and Tourette's syndrome.[39] The striatum is a central component of the basal ganglia that collects and processes information coming from the cerebral cortex and the thalamus.[40] The Irritation of the striatum causes general muscular contraction on the opposite side of the body.[41].So basal ganglia and specially striatum are now widely recognized as being engaged in activity related to learning. Interactions between the dopamine-containing neurons of the midbrain and their targets in the striatum are critical to this function.[421543]

FEF(Frontal eye field) neurons have been implicated in numerous functions including visual search , saccade preparation and inhibition ,perceptual choice ,visual attention, visual working memory , trans-saccadic stability, planning saccade sequences, eye–head coordination , and anticipating reward .[44] Complex behavioral tasks usually necessitate activation of caudate nucleus neurons. [45] The outputs of the basal ganglia are directed to some of the motor networks in the brain stem. They include the projection to the superior colliculus (SC) (for eye-head orienting), the pedunculopontine nucleus (possibly for locomotion), and the periaqueductal gray matter (possibly for vocalization) and autonomic responses. [43] The visuo-oculomotor region is located in the region of the caudate nucleus where the head changes into the body, mostly posterior to the anterior commissure. This region largely includes the region that receives inputs from the frontal eye fields (FEF) and the Supplementary eye field (SEF) and partly includes the region that receives inputs from the dorsolateral prefrontal cortex.[43 45] A large body of work indicates that the neurotransmitter dopamine in the striatum plays a crucial role in reinforcement learning. [46] Saccade-related activity has been found in various nuclei in the basal ganglia, including the SN, Caudate nucleus, sub-thalamic nucleus (STN),and Globus pallidus (GP)[45] . 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) will be referred to here as the pallidum

Striatum Histology and its Role on Movement

Golgi type I cells are the main neuron in striatum that are morphologically distinguished by a large soma and wide dendritic arborisation . These neuron are modulated by two different neurotransmitter , glutamate that mediated by neurons which originated

from cortex and another neurotransmitter that mediated by dopaminergic neurons are originated from midbrain.[47 48 49 40] . The Caudate nucleus is a large structure in the basal ganglia and, together with the putamen are called the striatum or the dorsal striatum.[45] 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[2850 5117]. Nigrostriatal dopaminergic projections are essential regulators of motor circuits.[51] Bradykinesia and associated problems in movement , Tremor , rigidity and loss of postural control are symptoms of denervation of this tract such as seen in Parkinson.[10182124] The mesolimbic and nigrostriatal dopamine (DA) systems play a key role in the physiology of reward seeking,[2812620] motivation and motor control[1021].They are also consider as pathogens of Parkinson's and Huntington's disease, schizophrenia and addiction. Control of DA release in the striatum is tightly linked to firing of DA neurons in the ventral tegmental area (VTA) and the substantia nigra (SN).[52]

Dopamine Role in reinforcement and punishment

Dopamine has functions in two key areas: movement control and cognitive effort.[54] Cognitive effort is done in two classes include: working memory and decision-making.[55]. The idiom reinforcement explain processes that keep or enhance behavior, while the term punishment explain processes that reduce behavior.[41]

One contra indication against Dopamine's main role

The central region of the human retina, the fovea, is responsible for delicate and precise vision. The neurons that maintaining visual stability and controlling eye movements (oculomotor system) steadily brings targets of interest into the fovea via ballistic eye movements (saccades). The fovea thus serves both as the locus for fixations and as the oculomotor reference for saccades.[56] Our decision where to move our eyes is influenced by many factors, such as knowledge about the visual world, expectations of what will happen next, and visual input from the world around us. Although many objects around us compete for selection, we can only make one eye movement at a time.[57] The main challenge for the oculomotor system in a complex environment is to select when and where to move the eyes to land near targets of interest. Emphasis is on three oculomotor behaviors: eye-head coordination(gaze control), smooth pursuit that allow the eyes to closely follow a moving object and saccades, and on their interactions with vision.[58] Distractors close to the target affect the saccade landing position (known as the global effect) or in the other hand, When two target elements are presented in close proximity, the endpoint of a saccade is generally positioned at an intermediate location ('global effect'),[5960] while remote distractors prolong saccade latencies to the target (known as the remote-distractor effect).[57]

A direct effect of the strobotraining, shows that dopamine intermediation is related with the peak speed of saccades that started to increase briefly after the presentation of a visual transient. Buonocore et al had a experiment that [61–64] showed before their contributors made a saccade from the center of the screen to a target at up to three different eccentricities, short (20 ms) flashes at different direction in time. They found saccadic inhibition from about 50 ms to 90 ms after flash onset.[63]

Saccade

Saccadic eye movements are rapid movements of the eyes that reorient the line of sight.[65] There are three saccadic eye movement (SEM) include : 1) targeted versus untargeted SEMs, 2) auditory cued versus visually cued SEMs, and 3) stochastic versus rhythmic SEMs.[66] Three different cortical areas are capable of triggering saccades. These area are include I) the parietal eye field (PEF) triggers saccades made reflexively on the sudden appearance of visual targets ; II) the frontal eye field (FEF) involved in disengages fixation, and triggers intentional saccades to visible targets, to remembered target locations, or to the location where it is predicted that the target will reappear;III) the supplementary eye field (SEF) on the medial wall of the frontal lobe, probably involved in the temporal control of sequences of visually guided saccades and in eye-hand coordination,and in controlling saccades made during head or body movement .[666768] A putative cingulate eye field (CEF) , would be involved in motivational modulation of voluntary saccades. The dorsolateral prefrontal cortex (dlPFC) in the mid-frontal gyrus is involved in reflexive saccade inhibition and visual short-term memory.[67] Besides these motor areas, Dorsomedial frontal cortex (DMFC) makes an important contribution to generating sequential saccades and fixations but not single saccades and fixations. [69]

The motor programs elicited from the superior colliculus control orientation movements. Stimulation of different loci within the superior colliculus results in saccadic eye movements in different directions and amplitudes[7071].

In the basal ganglia-superior colliculus pathway that is an inhibitory pathway through GABA . In this pathway ,the caudate nucleus and the rostral part of the putamen, input stations of the basal ganglia, receive projections from the FEF , through a series of synapses within nuclei of the basal ganglia goes to superior colliculus , but reaches it indirectly**.** In this pathway there is in cognitive events intervening between vision and action, such as memory, target selection and saccade choice and valuation.[7273]

Direct pathway arises from cerebral cortical neurons specially Frontal eye field region and targets the colliculus and pons directly. [73]These cortical projection neurons exert their effects on the SC and are excitatory and directly influence the colliculus for the generation of voluntary saccades . Neurons in the FEF not only through the direct projection to the SC, especially to its deeper layers, but also by way of the basal ganglia [7273] [7465] Huntington's disease (HD), a progressive neurological disorder involving degeneration in basal ganglia structures, leads to abnormal control of saccadic eye movements.[75]Besides variety of signals are sent from SC to FEF, with presaccadic signals appearing to inform the cerebral cortex about upcoming saccade.[76]

3. EXPERIMENTAL SET-UP AND MEASUREMENTS

Dopamine and Environmental light

Converging evidence suggests that environmental light has influence on Dopamine changes and consequently on the mood and cognitive functions. As well as unfortunately pervasive exposure to nighttime lighting is caused circadian disruption is associated with increasing incidence of certain cancers, metabolic dysfunction and mood disorders. (53)

In one study Cowley et al showed that bright light can alleviate low mood in patients with seasonal affective disorder (SAD), no seasonal major depressive disorder, antepartum depression, eating disorders and those with subsyndromal winter mood disturbances. and as well showed that enhancement of DA function may be responsible for some of the beneficial effects of light.(54). In another study Romeo et al had shown that Light induces neuromelanin formation in the substantia nigra. And as well Light induces reduction of tyrosine hydroxylase (TH)-positive neurons in the substantia nigra. (55)

Stroboscope training and Dopamine role

Stroboscopic visual training (SVT) is the practice of placing individuals under conditions of intermittent vision, often using specialized eyewear, in an attempt to enhance visual and perceptual skills.[7778]

Dopamine D2 receptors are involved with wakefulness [79] . Many studies have shown that intermittent, or stroboscopic, visual training (i.e., practicing while only experiencing snapshots of vision) can enhance visual–motor control and visual cognition[80]. In this article we want to study its mechanisms in brain. Regarding to previous research we know that *light flashes and* shutter glasses have the same effect upon the visual-motor system, as reported for space and aviation industry in[81] As shown in figure 2 , Intermittent, or stroboscopic, vision provides an interesting manipulation because it interrupts the normal flow of visual information, and therefore reduces the feedback that is available to guide movements as they are carried out.[82]

Research repeatedly reports athletes' enhancements of color vision, better peripheral vison, time dilation and other stamina. [15,79,83–85].

Strobotraining apparently speeds-up RTs by unknown cause. For example: ball athletes do not follow the ball's trajectory , but rather observe the initial movement of the ball, remember it, and with a rapid eye saccade, go to a projected final position of the ball's path [82,86] .

The influence of light flashes on dopamine levels is proven in epilepsy research and patients' experience [87,88]. There was the tachistoscope used for such experiments [89]. The modern shutter glasses are passive and do not give light. They only pass or inhibit light. The working, is that the shutting off light induces a flash of light after the shutter opens (figure 2). This remarkable phenomenon is the explanation that the shutter glasses and the old tachistoscope have similar impact upon the brain's Dopamine levels.

Figure.2 [90]the Senaptec strobe glasses With the lenses in clear state.

The Stroboscopic frequency and Montage

The stroboscopic frequency level for the strobe condition varied across training sessions. Frequency can alter from faster to slower rates at set time intervals between organized drills.[80] The strobspectacle that Wilkins et al used it in their study was Senaptec Strobe glasses (figure 2) which those glasses flicker from clear to opaque states at eight different frequencies, ranging from 6 Hz (level 1; deemed easiest due to receiving the most visual samples) to 1 Hz (level 8; deemed hardest due to receiving the fewest visual samples).They suggest that Stroboscopic visual training (SVT) may have the potential to improve the visual response time of elite youth athletes.[77] In studies by Appelbaum et al,[7,8,78,80,82] stroboscopic frequency Levels 2 – 4 (5 –3 Hz) are applied and is investigated the malleability of visual memory. Appelbaum showed in these papers that stroboscopic training can lead to general improvements in higher-level visual cognition, improvements in motion detection and central attention.[80,82] Reschke et al. showed that Shutter glasses have positive influence on motion sickness with a cycle frequency of 4 or 8 Hz and a short dwell (glasses clear) time (10–20 msec), producing a useful adaptation during either self or surround motion without the penalty of using disabling motion sickness drugs.[81,91]. They proved experimentally that shutter glasses have the same effect as stroboscsopic lightning.

3. CONCLUDING REMARKS

In last decade many researchers showed that the stroboscope has the direct correlation to central dopamine (DA) function. Stroboscopic visual training (SVT) that is done by putting people under conditions of alternative lights, via specialized eyewear, in an attempt to enhance visual and perceptual skills. Stroboscope training use from intermittent such as environmental light has influence on dopamine like what shutter glasses do. Stroboscope training with different frequency has different effects for instance, as mentioned above it can lead to general improvements in higher-level visual cognition, improvements in motion detection and central attention and as well it can improve visual memory. Since its positive effects on enhancement of visuo-motor skills, Stroboscope training is used for increasing athletic abilities. Stroboscope training also has positive effects on motion sickness. Besides the influence of light flashes on dopamine levels is proven in epilepsy research and patients' experience. The perspective of this type of training, as reviewed above, is the A. on the one hand the health benefits for trainees, and B. on the other hand the improvement of trainees visuomotor abilities.

With regard to A. it is demonstrated in mouse models of neurodegeneration by Adaikkan et al[92]that entraining gamma oscillations in the visual cortex, hippocampus, and prefrontal cortex, mice subjected to chronic, daily training from the early stages of neurodegeneration showed a preservation of neuronal and synaptic density across multiple brain areas and modified cognitive performance. The gamma band is available in the applied eyewear!

Even in sports at schools for young adults the envisioned training is beneficial. In a perspective on dopamine's roles does Berke[93]explain its benefit in moving and learning.

The known relation of dopamine levels to psychiatric disorders[10]can be applied by Vision training to the benefit of psychiatric patients. Even mild health conditions might benefit from the malleable dopamine levels in brains, see for instance the influence on motivational states[94], by light.

In the matter of B., i.e. improving athletes and sporting abilities is control of dopamine levels a thus far hidden link in understanding the mental part of the lack of results and the other extreme the excessive results at world champion's level. The perspective here is on the mental reports of winners, their mind-sets. This is dopamine induced and becomes manipulatable by the vision training. Because the effect of SVT training on the eye-motor coordination and reaction time of athletes, highlighted the role of enhancement by the dopaminergic circuits of the brain in the cortical and subcortical areas.

Said in detail: the method increases the balance and coordination of purposeful movements of athletes, as amply shown in training and exercise programs of hockey[95],soccer[9677], volleyball[4],and other sports. This was confirmed by three of us in our previous study.

4. TERMS AND DEFINITIONS LIST

VTA: Ventral tegmental area
DA: Dopamine
STN: Substantia nigra
CD: Caudate nucleus
SVT: Stroboscopic visual training
FEF: Frontal eye field
HD: Huntington disease
PEF: Parietal eye field
SEM: saccadic eye movement
dlPFC: dorsolateral prefrontal cortex
DPFC: Dorsomedial frontal cortex
SEF: supplementary eye field
CEF: Cingulate eye field
SAD: seasonal affective disorder
TH: tyrosine hydroxylase
OFC: orbitofrontal cortex
SNpc: Substantia nigra pars compacta
GPCRs: G protein-coupled receptors

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