International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

The Effects of Fluctuations in Dopamine Levels on Creative Thinking and Expression in Visual Art

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Abstract
This research qualitatively analyzes the effects of abnormalities in dopaminergic functioning on visual art through the evaluation of Parkinson's Disease, Schizophrenia, Bipolar Disorder, and Attention Deficit Hyperactivity Disorder (ADHD). In addition, the research discusses the examples of famous visual artists who have suffered from these disorders and draws potential connections between changes in art style and productivity, and changes in dopamine. Dopamine can impact creative thinking and expression in visual art through its influence on factors such as perception, imagery, divergent thinking, novelty-seeking, and reward-seeking behaviors. Overall trends show that mental states that induce an increase in dopaminergic activity can serve as a conducive condition for improved artistic output, through an increase in novelty seeking, energy, divergent thinking, and unique demonstrations of elements and principles of art.

I. Introduction

Over the past century, research has identified remarkable changes in the cognition of patients suffering from neurological disorders and its profound effect on the perception and output of visual art. Studies such as those conducted by Lauring et al. (2019), showing a drastic increase in artistic interest among patients with Parkinson's Disease on medication, and Burch et al. (2006) establishing a high correlation between schizotypal personality traits and visual artists, raise the question of whether or not there is a predictable effect of alterations in dopaminergic activity caused by these disorders on the artistic process and personality.

Although there has been extensive research on the effects of dopaminergic activity on creativity and visual art that is specific to the causative neurological disorder, there has been little research that bridges the gap between the various disorders, medications, and case studies that have been documented on the same. The ability to make objective predictions of the effects of these dopamine fluctuations on visual art, through a cumulative review of all of the information collected on various disorders and their medications, could serve as a diagnostic tool for these disorders and even help visual artists suffering from these disorders sustain their passion for art and quality of life.

According to Ludwig (1989), three forms of creativity can be found:

1. the creative person
2. the creative process

3. the product of creativity.

Through the study of disorders causing dopamine abnormalities, and the analysis of the timeline and output of relevant famous artists who have suffered from these disorders, this research aims to analyze the effects of dopamine dysregulation on these three forms of creativity through the lens of visual art.

Although there is an extensive list of dopamine-impacting neurological disorders, this review focuses on Parkinson's Disease (PD), Schizophrenia, Bipolar Disorder, Depression, and ADHD, to provide an in-depth conclusion on how changes in dopamine resulting from these disorders reflect in terms of visual art.

Dopamine

Dopamine is a neurotransmitter that plays a critical role in learning and motivation. (Mohebi et al. 2019) The largest dopamine-rich areas of the brain are the substantia nigra and ventral tegmental area in the midbrain. (Olivia Guy-Evans et al. 2022) The major dopamine pathways, highlighted by Latif et al. (2021), that will be discussed in the paper due to their involvement in multiple neurological disorders of interest include:

1. **Nigrostriatal pathway**- This pathway starts from the substantia nigra and ends in the striatum. Damage to this pathway is associated with PD
2. **Mesolimbic pathway**- This pathway stretches from the ventral tegmental area to the nucleus accumbens and functions in reward and emotion. Mesolimbic dopamine is hence released during pleasurable situations, such as eating or drug abuse, and is associated with schizophrenia, PD, and ADHD
3. **Mesocortical pathway**- This pathway connects the ventral tegmental area to the cerebral cortex, functions in emotional and cognitive behavior, and is also associated with PD. (Latif et al., 2021)

The image below depicts the key dopamine pathways that have been discussed above.

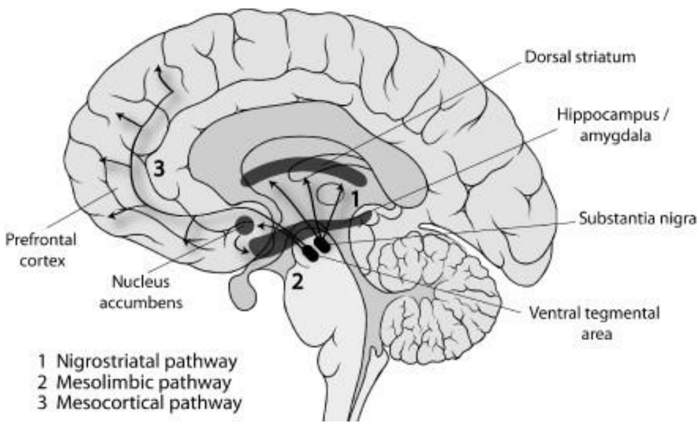


Figure I: Pertinent Dopaminergic Pathways in the Brain, adapted from 'Argument for a non-linear relationship between severity of human obesity and dopaminergic tone' (Horstmann et al. 2015)

Tonic vs Phasic Dopamine

According to Grace (1991), tonic dopamine is the spike-independent release of dopamine triggered by glutamate released from prefrontal cortical afferents. It underlies background, steady-state levels of extracellular dopamine in subcortical structures.

On the other hand, phasic dopamine is short-term dopamine release caused by the firing of dopamine neurons in response to behaviorally relevant stimuli. Phasic dopamine is released in large amounts but is rapidly removed from the synaptic cleft once it activates postsynaptic dopamine receptors.

High levels of tonic dopamine can reduce the amplitude of subsequent phasic responses of dopamine, and the converse applies to low levels of tonic dopamine. This is because once neurons receive a signal that there is already high tonic dopamine release, (large amounts of dopamine outside the cell), phasic responses to stimuli become smaller.

Deviations in tonic and phasic dopamine release play a key role in the cognitive symptoms of disorders that can affect artistic output. For instance, dysregulation in tonic and phasic dopamine release has been associated with delusions in schizophrenia and attention deficits in ADHD. (Grace, 1991)

II. THE NEUROPSYCHOLOGY BEHIND CREATIVE EXPRESSION

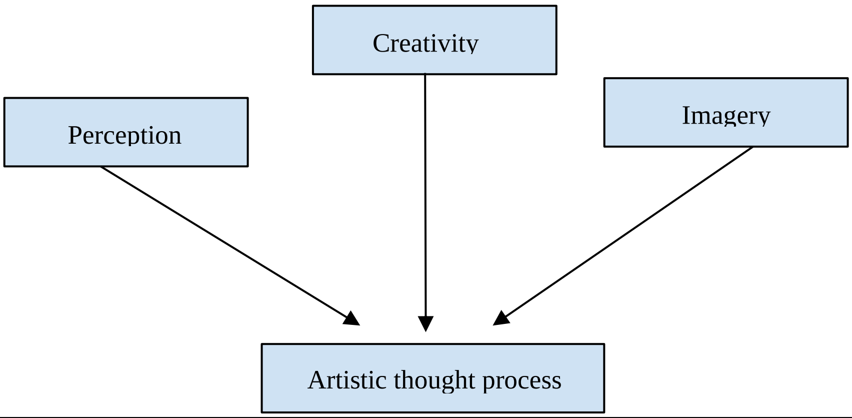


Figure II: Factors that contribute towards the artistic thought process.

Although often thought of as synonymous, creativity, perception and imagery play distinct roles in the initial steps of artistic output: creativity allows for a free mode of idea generation through divergent thinking; perception influences the interpretation of an artist's environment, and as a result, the individual's artistic representation of that environment; and imagery impacts the degree of accuracy in mental visualization and representation.

Although creativity is the primary focus of this research, due to its significant role in enabling an artist to leave a distinctive impression in the field of art through their unique approaches towards the subject, processes such as perception and imagery, which are integral to the creation of art, will also be reviewed.

Creativity

Creativity plays a crucial role in an artist's ability to innovate and execute ideas that are novel and unique. Dopamine and creativity are closely interconnected, with creativity being so integral to our everyday functioning that it can be genetically predetermined.

Genetics, Dopamine, and Creativity

A polygenic risk score analysis showed that the genetic risk for schizophrenia and bipolar disorder can predict a creative occupation, therefore genetic polymorphisms related to mental disorders could carry positive effects: creativity and altruism. (Sotiropoulos and Anagnostouli 2021)

The following genes participate in dopaminergic pathways and creative thinking: Taq1A, DRD2, (genes involving dopamine D-2 receptor), and COMT (the enzyme responsible for the breakdown of dopamine). Underlying endophenotypes of these genes include decreased latent inhibition (increases motivation to create art) and increased novelty seeking (an important trait of visually creative people (Lauring et al., 2019)). (Sotiropoulos and Anagnostouli 2021)

Convergent vs Divergent thinking

Two processes are central to creativity: divergent thinking and convergent thinking. Differences between convergent and divergent thinking can be observed in underlying memory processing, personality, and neurochemistry involving dopaminergic pathways.

Divergent thinking is a style of thinking that allows idea generation in which the selection criteria are more vague and allow room for more than one correct solution. Hence, divergent thinking involves the flexibility of the mind, and scores on divergent thinking tests show positive correlations with involvement in real-life creative activities, self-rated creativity, and objective measures of creative achievement.

Convergent thinking, on the other hand, is a style of thinking that allows finding single, well-defined solutions to a problem. This requires more persistence and focus.(Zhang et al., 2020)

There has been increasing evidence that creativity is a function of dopaminergic modulation. Divergent and convergent thinking could be demonstrated to be differently related to the neuromodulatory dopamine system in the brain. While striatal and nigrostriatal dopamine are associated with divergent thinking, prefrontal dopamine, and the mesocortical dopaminergic pathway are associated with convergent thinking. (Zhang et al., 2020)

Akbari Chermahini and Hommel (2012*)* confirmed that eye blink rate (EBR) is positively correlated with dopaminergic activity. Convergent thinking was found to be negatively correlated with EBR, suggesting that higher levels of dopamine impair convergent thinking, possibly leading to better creativity and ideation when it comes to creating art. (Chermahini & Hommel, 2010)

Akbari Chermahini and Hommel (2012*)* showed that despite the commonly assumed idea that positive mood improves creativity, a non-linear relation between dopamine and flexibility has been found. The impact of mood on divergent thinking can depend on an individual's tonic dopamine level, and the idea that low dopamine results in low creativity might not be applicable universally.

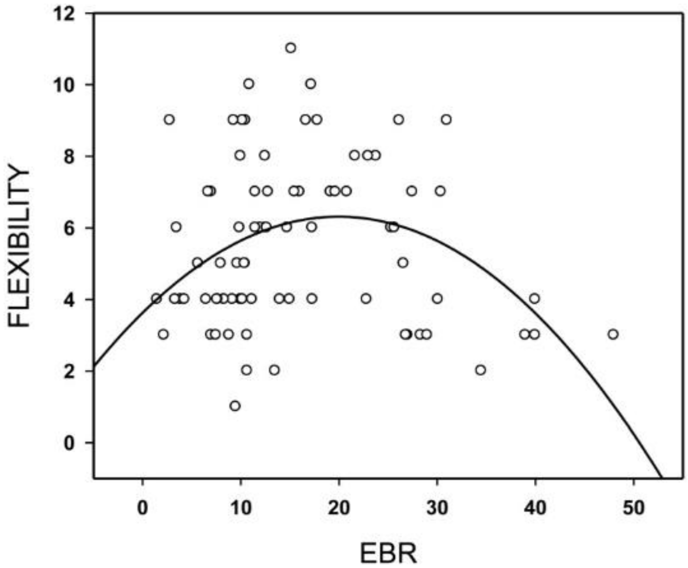


Figure III: Relationship between EBR and the ability to think divergently. Adapted from 'More creative through positive mood? Not everyone!' (Akbari Chermahini and Hommel 2012)

Through the assessment of mood, performance in a divergent thinking test, and EBRs, a clinical marker of individual dopamine levels, researchers were able to deduce that inducing a positive mood raised EBRs. However, only those with below-median EBRS, but not those with above-median EBRs, benefited from positive mood in terms of their ability to display divergent thinking. (Akbari Chermahini & Hommel, 2012) Disorders that lead to below-median tonic dopamine include schizophrenia and ADHD.(Grace, 1991) This means that those affected by schizophrenia and ADHD experience better creativity when in a positive mood induced by dopamine.

Imagery

Nearly any cognitive process that might be gained from sensory stimulation utilizes mental images (Pearson 2019). On comparing the proportion of cortical tissue assigned to processing visual information with that of other senses, it is clear why visual-mental imagery has tended to dominate research among the five senses. Imagery vividness and strength differ from one individual to another: it can be completely absent or photo-like. Extremely vivid, life-like imagery is known as hyperphantasia and is linked to anxiety and schizophrenia. (Pearson, 2019)

When generating images, we are combining context that our senses have previously been exposed to and is stored in our memory. It can therefore be inferred that positive symptoms of schizophrenia such as hallucinations and other experiences that occur as a result of mental disorder can serve as context and hence have a strong effect on visualization during artistic ideation.

Strong visual imagery, which is associated with increased dopaminergic activity, can enable people to simulate experiences in their minds without the presence of external stimuli, a function that is key to the execution of artwork.

Perception- Dopamine in the Eye

Visual perception is our ability to interpret and make sense of the visual information we receive from stimuli in the environment. Artwork that depicts an artist's environment can serve as a direct reflection of how they perceive it.

Cones, present in the retina, are specialized neurons that are an extension of the brain. As a result, cones can also be affected by dopamine present in the brain tissue. Dopamine has receptors on the cones themselves (Zaidel 2011), and too much or too little dopamine can impact visual perception. (Djamgoz et al. 1997; Masson et al. 1993)

Deficiencies in perceptual organization ,organizing sensory information into meaningful and coherent patterns, and surround suppression ,the response of a neuron to a certain stimulus is diminished by surrounding stimuli, have been observed in patients with schizophrenia. Deficits also include the misperception of:

1. Size
2. Distance
3. Color
4. Brightness
5. Contrast
6. Binocular vision. (Bettelheim et al. 2024)

These misperceptions could be linked to hallucinations and delusions that occur in schizophrenia, or in artists exhibiting schizotypy, simply skew their perception of the environment.

Retinal hyperdopaminergic conditions cause malfunctions in the magnocellular pathway, which carries information about large, fast things, causing low spatial frequency perceptual distortions. Patients with an elevated magnocellular pathway report feelings of an "abnormal intensity of environmental stimuli, feelings of being flooded and inundated, and inability to focus attention to relevant details". During the creation of art, feelings such as these can lead to an inability to focus on the specific elements of the artwork. Excess dopamine in the retina can also cause increased brightness and hyper-intense color perception. (Bettelheim et al. 2024)

As a result of these changes in perception, a patient suffering from hyperdopaminergic activity, such as with schizophrenia, could struggle with creating or interpreting art due to difficulties in focusing on details or being overwhelmed by visual stimuli. On the other hand, it could also lead to

Reduced dopaminergic activity in the retina, on the other hand, can cause cone-amacrine cell dysfunction. This leads to reduced sensitivity to contrast, poor color vision, and loss of visual acuity. Another effect would be the reduced interactions between neurons and rods (signal light and dark), leading to reduced surround suppression and hallucinations. Spatial frequency processing (understanding patterns of light and dark in an environment), which is dependent on dopamine receptors in the retina, is also dysregulated. These alterations in perception could be observed in the artwork of PD patients. (Lee et al. 2022)

It appears as though hyperdopaminergic conditions are ideal for creativity and imagery, with high levels of dopamine allowing for stronger imagery and increased divergent thinking. Dopamine fluctuations disrupt perception, and although this can induce feelings of overwhelm, it could also be beneficial for an artist as it allows them to portray environments that are unique and personal to that individual's experience.

The process of artistic ideation and execution does not end with creativity, perception, and imagery. Dopamine's role in the process of the execution of these ideas has also been heavily researched, and the table below illustrates aspects of executive functioning that lead to the creation of art. Understanding the role that dopamine plays in each of the factors listed in the table below through attribution of these traits and processes to various brain regions and pathways would help us better understand the cause-and-effect relationship between dopamine and artistic output. The table below summarizes factors that can influence artistic motivation and success as a visual artist, and the process of artistic output. This overview serves as a structured understanding of the intersection between motivation, the artistic process, and the personality involved in visual art, which will be further understood in the context of dopamine in Section III.

Factors that lead to higher motivation to create art	The process of artistic output	Personality traits that lead to success as a visual artist
1. Higher drive for reward 2. Reduced inhibition 3. Higher executive control 4. Heightened internal focus on creative problems and inner emotional state	1. The initial ability to adopt a free mode of idea generation. This could also include the desire/ability to pursue artistic questions 2. Generation of ideas 3. Pursuing certain outputs 4. Execution of an idea through producing artwork 5. Investing Time and attention to stick with an artwork once begun	1. Openness, characterized by imagination and insight 2. Extraversion 3. Divergent thinking 4. Novelty seeking 5. Lower inhibition

Table I: Factors involved in the creation of art (Lauring et al., 2019)

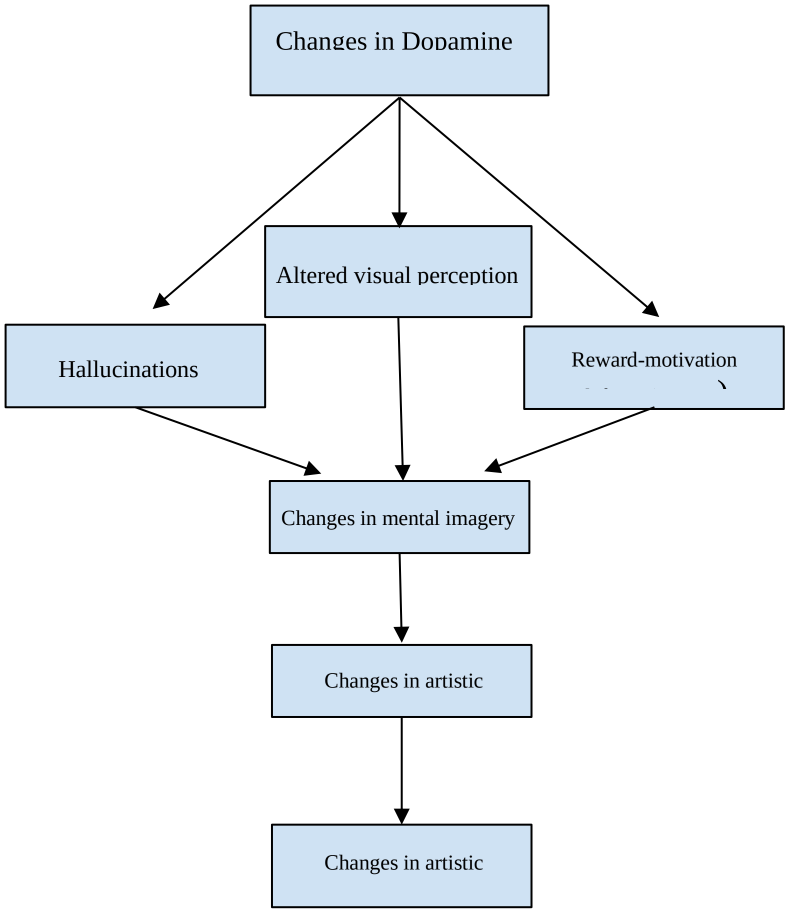


Figure IV: Step-by-step results initiated by exemplar effects of dopamine fluctuations

III. ANALYSIS OF DOPAMINE-RELATED DISORDERS AND THEIR EFFECTS ON ARTISTS

Parkinson's Disease

PD is caused by the death of dopaminergic projections from the substantia nigra to the caudate nucleus and striatum. The death of dopamine neurons in the striatum can lead to a decrease in the patient's divergent thinking.(Gao et al., 2021) This also leads to low levels of dopamine in the basal ganglia. Lewy bodies (clumps of proteins that build up inside neurons) that are found between neurons and on neurites are pathological hallmarks of the disease.(Zhou et al., 2023)
The first symptoms of Parkinson's involve difficulties with movement: this could be a tremor, bradykinesia (slowness of movement), or rigidity. Individuals with PD also experience psychiatric symptoms such as depression, hallucinations, anxiety, and psychoses. (Frcpc et al., 2011)
Degeneration of mesolimbic dopamine, norepinephrine, and serotonin pathways along with degeneration of orbital–frontal circuits and subcortical structures are considered to be associated with the development of depressive symptoms in PD patients. These depressive symptoms can lead to a lack of motivation and executive function in PD patients. (Latif et al., 2021)
Despite PD being characterized by reduced flexibility, conceptualization, motivation, and visuospatial abilities, it has been found that certain cases of PD patients on dopamine agonists and replacement show an increase in creativity during PD. Creativity in PD is linked to (but not

proven to be caused by) dopamine agonist therapy, and tends to disappear after the reduction of dopamine agonists. (Lhommée et al., 2014)
Levodopa, a commonly used medication to treat PD, is the precursor to dopamine. It is hence used as a dopamine replacement agent for the treatment of PD. Levodopa crosses the blood-brain barrier and is then taken up by surviving neurons in the nigrostriatal pathway.(Gandhi & Saadabadi, 2023) Dopamine agonists, on the other hand, bind directly to dopamine receptors and activate cellular signalling pathways.(Brooks, 2000)

The following studies show a positive overall trend in how dopaminergic treatments during the progression of PD impact the motivation to create art and changes in style.

Study	Outcome
Dopamine and the biology of creativity: lessons from Parkinson's disease	A woman suffering from PD showed a strong exacerbation of her painting activity upon treatment with high doses of levodopa. A change in her art style was also observed: fixed, rigid shapes changed to fluid structures, and dull, darker colors turned brighter and more expressive. (Lhommée et al., 2014)
Art and Parkinson's disease	A study examining the artworks made before and after the onset of PD in a sculptor and 40 other professional artists found no decline in pictorial capacity (detail, color range, color accuracy, etc). In addition to this, it was found that certain participants had an increased focus and urge to make artwork, and their behavior was attributed to anti-parkinsonian medication. Stylistic changes such as "awkwardness with perpendicular strokes", "unusual manner of hatching", and "changes in format and theme" had been observed. However, this study lacked objectivity since results were based on the author's observation and subjective judgments from participants, along with no record of medication. (Lakke, 1999)
Art movements	Noted that one artist believed that upon treatment with anti-parkinsonian medication, her creativity increased and her paintings had improved. She recorded a change in her style which was less precise but more vibrant.(Pinker, 2002)
Changes in artistic style and behavior in Parkinson's disease: behavior and creativity	Reported an amateur painter whose interest in art decreased 8 months before a PD diagnosis had been made, but following levodopa and other dopamine agonists resumed painting.(Kulisevsky et al., 2009)
Turning off artistic ability: the influence of left DBS in art production	Collected paintings from a patient with PD before and after deep brain stimulation (DBS). A panel of nine judges concluded that post-DBS, rendering, skill, and evoked thoughts/feelings declined significantly. (Drago et al., 2009)

Table II: Studies that highlights the effects of PD medication on artistic thinking and expression

The changes in some individuals with PD, especially in those with a new drive to make art presumably are tied to some corresponding brain changes brought about by either damage or over-activation. It is hypothesized that these changes might occur in the ventral striatum or orbitofrontal cortex amongst a few others.(Lauring et al., 2019)

The key proposed factors involving PD-related artistic change include:

1. Damage to the nigrostriatal dopamine pathway, leading to the initiation of dopamine replacement and dopamine agonist therapy. Dopamine agonists can encourage positive feedback on the creative artist's work by acting on the nucleus accumbens, one of the main components of reward circuits.(Lhommée et al., 2014)
2. Minor damage to the mesolimbic pathway and striatal and midline structures. These are connected to introspection, flexibility, associations, idea generation, reward seeking, motivation, and impulsiveness. Dopamine agonists can cause increased activity in these regions if they remain intact.
3. Selective damage/reduced function in the mesocortical pathways as well as lateral orbitofrontal cortex.

(Lauring et al., 2019)

This combination of alterations in dopamine pathways is considered to increase motivation to create art and the reward derived from it. It could also lower inhibition of urges to create and respond to artistic ideas.

Schizophrenia

Schizophrenia is a mental illness marked by hallucinations, delusions, disorganized speech, avolition, and cognitive impairment. (*Schizophrenia*, 2024) and is associated with neurotransmitter dysfunction in the dopamine and glutamate systems. (Brisch et al., 2014) Excessive dopamine activity in the mesolimbic pathway is thought to cause positive symptoms of schizophrenia, while reduced dopamine levels in the mesocortical pathway may underlie negative symptoms and cognitive deficits.

Elevated striatal dopamine synthesis activity can also lead to increased divergent thinking in schizophrenics. (Boot et al., 2017)

One of the most enduring theories of schizophrenia has been the dopamine hypothesis (Seeman & Kapur, 2000). The discovery of the dopamine D2 receptor led to repeated confirmation that it is the primary site of action for antipsychotics such as clozapine and quetiapinedopamine overactivity, suggesting that could be the root cause of the psychotic element of schizophrenia. Numerous post-mortem studies have shown that the number of D2 receptors in the striata of schizophrenics are elevated. (Seeman & Kapur, 2000)

Research using objective measures of imagery found that the surface size of both the V1 and V2 negatively predicts the strength of visual imagery: this means that those with stronger imagery are likely to have smaller primary visual cortices. It has also been proven that the size of the V1 and its total number of neurons is reduced in schizophrenia compared to normal healthy brains, which further strengthens the belief that schizophrenics have stronger visual imagery, allowing them to create art that is accurate and original, leading to the potential replication personal experiences in detail. (Pearson, 2019)

(Glicksohn et al., 2001) compared schizophrenics, visual artists, and controls along a series of tasks that recruit symbolic and syncretic cognition. Syncretic cognition is associated with the dedifferentiation of perceptual qualities in subjective experiences, the most predominant example being synaesthesia: in synaesthesia, two perceptual modalities become dedifferentiated (for example, color and taste). Werner (1948) believed that artistic perception and creative thinking could rely on syncretic cognition since dedifferentiation allows for flexibility in perception and thought. This could entail some incoherence of thought or 'looseness' of thinking. Upon testing participants with 3 tasks (The Open Circle Task, Color-Mood Synaesthesia, and The Absorption Scale) that assess syncretic cognition, it was found that 2 out of these 3 tasks showed a high degree of syncretic cognition in schizophrenics and visual artists. Hersch (1962) showed that both schizophrenics and artists had access to a more syncretic mode of thinking and that controls did not. These findings can be interpreted as being the 'positive' symptoms of schizophrenia: loose associations and pseudo-hallucinatory imagery

Symbolic cognition involves symbol production and symbol comprehension and is related to the state of consciousness of the individual. Schizophrenics characteristically on measures assessing symbol comprehension. It has been suggested that this is due to the inability to achieve an 'abstract attitude'.

(Burch et al., 2006) used a range of personality and creativity measures (such as the O-LIFE and NEO-FFI) between visual artists and non-artists. Results showed that the visual artists group scored higher than the control group on measures of positive-schizotypy, disorganized schizotypy, openness, and divergent thinking, and lower than the control group on agreeableness, pointing to a strong link between schizophrenia and artistic qualities.

Yayoi Kusama

Yayoi Kusama is a Japanese visual artist. Although her official psychiatric diagnosis is uncertain, she is believed to have suffered from severe psychosis and obsessive-compulsive behavior as a result of childhood trauma: childhood trauma is characterized by increased striatal dopamine release and is associated with positive symptoms of schizophrenia and divergent thinking (Brisch et al. 2014; Cancel et al. 2019).

A majority of her early works involved painting nets on canvases up to 33 ft. long. While she was creating these, she witnessed patterns expanding beyond the canvas and onto the area around her. This inspired her to become an environmental artist, pushing her to create the Infinity Mirrors series: she shifted her focus towards expanding her artistic projections outside of the canvas and into interactive spatial installations. (Tareen, n.d.) This is an example that highlights the possibility of hallunications caused by mental illness serving as inspiration for novel art concepts and ideas.

Figure V: “Infinite Obsession” exhibition by Yayoi Kusama at the Banco do Brasil Cultural Center in Rio de Janeiro in 2013. Adapted from Allure, Yayoi Kusama’s “Infinity Mirrors” to Go on a Tour

Upon the onset of her fame, Yayoi Kusamawould would go on to tell the Financial Times: “Georgia O’Keeffe-san (a friend that introduced her to other artists in New York) was worried about me… I was painting so much every day. I called the hospital many times and the doctor told me I should call the psychiatric hospital instead… The doctor said, ‘You are painting too much.’” Yayoi Kusama then admitted herself to the Seiwa Hospital for the Mentally Ill in 1977 and has not checked out since. (*True Superhero Yayoi Kusama: Art Inspired by Mental Illness*, n.d.) This addiction-like state that has been observed in Yayoi Kusama could have been caused by schizophrenia. Epidemiologic studies (Batel, 2000) have revealed a high degree of overlap between schizophrenia and addictive disorders. One of the hypotheses that have been suggested to explain this high comorbidity includes the possibility of shared biological vulnerability between schizophrenia and addiction:
A decrease in activity in the prefrontal cortex in schizophrenics is theorized to cause a decrease in tonic dopamine levels in the ventral striatum and nucleus accumbens. This can cause an abnormally large phasic dopamine response in the compensated ventral striatum. (Grace, 1991) It has also been found that art experience causes activation in the ventral striatum. (Lacey et al., 2011) Large phasic responses that recruit reward pathways in the presence of art can be a causal factor in the addiction-like state that was observed in Yayoi Kusama.

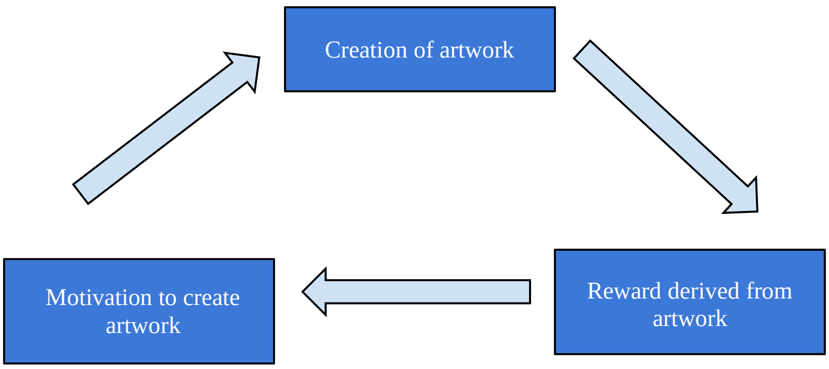


Figure VI: Motivation-reward loop that illustrates Yayoi Kusama's addiction to painting.

ADHD

Attention-deficit/hyperactivity disorder (ADHD) is characterized by symptoms such as inattention, hyperactivity, and impulsivity, causing impairment across cognitive and behavioral domains.

There have been genetic and environmental explanations for the cause of ADHD. Genetic studies identifying genes with polymorphisms associated with ADHD have found the most replicated genes to be two genes associated with dopamine (DRD4 and dopamineT1). (Mayseless et al., 2013; Turic et al., 2010)

Brain imaging studies have shown that brain dopamine transmission is disrupted in ADHD and the deficits caused by this could underlie symptoms like inattention and impulsivity. Individuals with ADHD have lower levels of tonic dopamine, which results in larger phasic responses. The low arousal theory states that because there is less extracellular dopamine, far more stimulation is required to get phasic dopamine activity that is similar to that of a neurotypical individual. This causes hypersensitivity towards environmental stimuli. (Grace, 1991; Volkow et al., 2009)

It has also been found that ADHD patients have reward and motivation deficits (Volkow et al., 2009). Reward-motivation deficits are characterized by abnormal behavior following reward and punishment conditions. The mesolimbic and nigrostriatal pathways have been proven to underlie reward and motivational deficits. (Czernecki et al., 2002)

In terms of visual art, having a reward-motivation deficit could mean that those with ADHD struggle to learn motor skills associated with objectively good visual art, due to their inability to respond effectively to potential positive or negative feedback.

The reward deficits in ADHD are characterized by:

1. a failure to delay gratification- this could result in the inability to pursue creative visual outputs over longer periods of time for those with ADHD
2. impaired response to partial schedules of reinforcement- this can cause difficulties in learning, developing skills, and improvement in the quality of art over time.

These abnormalities in reward-responses and inattention are though to be caused by lower D2/D3 receptors and dopamine availability in the accumbens and midbrain(Volkow et al., 2009) An fMRI study also showed decreased activation in the ventral striatum in patients with ADHD. (Plichta & Scheres, 2014; Rubia, 2018) In neurotypical individuals, the ventral striatum is activated in response to art images regardless of hedonic value. (Lacey et al., 2011) In ADHD patients, the lack of activation in the ventral striatum in the presence of rewarding stimuli, which in this case would be art, could lead to a lack of engagement and general disinterest in art.

Amphetamines as a treatment method for ADHD- what impact does this have on dopamine and creativity?

In North America, amphetamine is considered a first-line pharmacological treatment for children, adolescents, and adults with ADHD, and can be administered twice daily in short-acting compositions. (Hodgkins et al., 2012)

They enhance synaptic levels of monoamines in the brain by binding to dopamine transporters, but do so with varying selectivities and molecular mechanisms. In microdialysis studies, the effects of the drugs and amphetamine enantiomers have been studied on extracellular levels of monoamines in different brain regions in the rat. Amphetamines were found to cause large and rapid increases in dopamine levels in the striatum, increasing divergent thinking.
D-amphetamine is more potent than l-amphetamine, by being more effective in blocking dopamine and inhibiting its re-uptake. Due to this, the use of d-amphetamine can mimic the symptoms of schizophrenia and cause paranoid psychosis.
D-amphetamine has two opposing effects on dopamine neurons: a dopamine-mediated feedback inhibition and non-dopamine -mediated excitation. The inhibitory effect of d-amphetamine on dopamine cells involves the release of endogenous dopamine and the activation of dopamine receptors.(Shi et al., 2000)
It has been shown that amphetamines can increase levels of synaptic dopamine reversing the direction of dopamine from the inside to the outside of the cell. This increases mood, energy, and drive, and decreases the need to sleep, all factors that contribute significantly towards the motivation to create art. (Berk et al., 2007) With artists such as Jonny Cash and Andy Warhol being known to use amphetamines to induce creativity, (Lhommée et al., 2014) it can be suggested that the treatment of ADHD with amphetamines could cause an increase in creativity caused by perceptual change, and higher artistic output.

Bipolar Disorder
Bipolar disorder is a fascinating disorder to study in terms of its effects on artistic creativity and expression
due to the fluctuations in dopamine within the disorder itself.
Bipolar disorder type-1 is characterized by manic episodes that cause significant social and occupational impairment, whereas in bipolar disorder type-2, hypomanic episodes might not necessarily cause social/occupational impairment and rather present milder symptoms than mania. (Chan, 2021)

Characteristics of manic episodes	Characteristics of depressive episodes
Feelings of increased energy Rapid speech Extremely high self-esteem Impulsivity Irritability Rapid thoughts Delusions and Hallucinations	Depressive mood Loss of pleasure Difficulty concentrating Appearing slowed or agitated Indecisiveness

Table III: Symptoms of mania vs depression. Adapted from (Collier & MPH, 2023)

(Berk et al., 2007) suggested an increased dopaminergic drive during manic episodes and the converse in depressive episodes.

There may be a cyclical process in which increased dopaminergic transmission in mania causes a secondary downregulation of dopaminergic receptor sensitivity over time. This can lead to decreased dopaminergic transmission and consequently, a depressive episode. Stress caused by depression could activate dopamine neurons from the ventral tegmental area and stimulate dopaminergic transmission to targets in the limbic system. (Nestler & Carlezon, 2006)
With this information in mind, manic episodes may cause an increase in artistic output, and the converse for depressive episodes. Loss of pleasure and difficulties in concentration could mean that an individual experiencing a depressive episode would be unable to commit to artwork over long periods and could even lose the feeling of pleasure and reward that could have been derived from the activity before the onset of the depressive episode. Indecisiveness can also lead to slower and less efficient output. However, depression could provide a pessimistic assessment of what can be achieved.
The increased feelings of energy and rapid thoughts associated with mania, on the other hand, could be ideal conditions for ideation and creation in visual art. As seen in the case of Yayoi Kusama, hallucinations and delusions can also aid in the creation of new artistic ideas and forms of expression. High self-esteem can also cause an individual to increase their novelty seeking and lower inhibition, two characteristics that are important in visually creative people. Mania can also facilitate a wider range of imagination and provide the energy to push through on an activity.

Pharmacological evidence of the role of dopamine in bipolar disorder (Nestler & Carlezon, 2006)

1. In PD, giving high doses of dopamine precursors can produce mania-like symptoms, and upon withdrawal, these can switch to depressive symptoms.
2. Administering l-dopa to patients with BD can also produce hypomanic episodes. Similarly, amphetamines can produce a hypomanic-like state in healthy individuals.
3. Scarna et al. (2003) gave a group of participants who were suffering from mania a branched-chain amino-acid drink that reduced the uptake of dopamine precursors. This led to a decrease in the symptoms of mania.

(Santosa et al., 2007) compared creativity in patients with bipolar disorder, patients with unipolar major depressive disorder, creative controls, and healthy controls. They were assessed using the following scales:

1. Barron-Welsh Art Scale (BWAS): 86 images that subjects rate “like” or “dislike”. Higher scores reflect a preference for more asymmetrical and complex figures over more symmetrical and simple figures. Preference for asymmetrical and complex figures is higher among artists than non-artists and creative individuals have been found to have high BWAS scores.
    - BWAS Dislike
    - BWAS Like
2. Adjective Checklist Creative Personality Scale (ACL-CPS): reflects a putative personality component of creativity. Subjects indicate adjectives to separate groups of creative and non-creative individuals

3. Torrance Tests of Creative Thinking (TTCT): reflects divergent thinking. Subjects are encouraged to devise novel figurative and verbal responses to stimuli
   - Figural (TTCT-F)
   - Verbal (TTCT-T)

   The following conclusions were found:

1. Euthymic participants with BP (three-quarters of them were on medication) had a 45% higher mean BWAS total than the healthy control group.
2. The mean BWAS-Total score in BP was similar to that of creative controls
3. BP and not MDD patients had increased creativity.
4. BP had increased openness to experience compared to healthy controls (Nowakowka et al. 2005)

The subconscious dislike of BP patients towards simple and symmetric figures could be a result of their potential heightened sensitivity to complexity and openness to novel experiences. Hence, fluctuations in dopaminergic activity could induce artistic traits in BP patients, allowing them to appreciate unconventional art forms.

Vincent van Gogh

A famous artist well-known for his struggle with poor mental health is Vincent van Gogh.
He is said to have suffered from multiple psychiatric illnesses, including bipolar disorder, borderline personality disorder, and alcoholism. After his death in 1890, researchers named epilepsy as a possible underlying diagnosis.(Blumer, 2002)
Some of Vincent van Goghs most famous paintings such as Sunflower and Starry Night, depict scenes of nature, vivid colors, and organic paint strokes. These were created in the year 1888, during an intense manic episode.(Akiya, n.d.) He experienced phases of intense creativity (high dopaminergic activity) alongside periods of apathy and exhaustion (low dopaminergic activity). Upon van Gogh's famous breakdown involving him mutilating his ear lobe, the artist was admitted to a hospital. Vincent van Gogh would then go on to experience intense visual and auditory hallucinations, which could have aided in creativity and ideation while creating his paintings. In 1889, he experienced three new episodes, starting with states of disorientation, delusion, and paranoia, accompanied by auditory and visual hallucinations, and memory loss. Vincent van Gogh produced 150 paintings, including the Starry Night, during his stay at the asylum. (*Creativity and Mental Illness: Vincent van Gogh as the Archetypal Figure*, n.d.)

Edvard Munch

Edvard Munch was a Norwegian painter thought to have suffered from schizophrenia and social anxiety.
The traumatic experience of Edvard Munch's father's death is seen as setting him free artistically, initiating periods of creativity and increased productivity were accompanied by negative feelings of guilt, shame, and jealousy, and not the positive, euphoric feelings associated with mania and creativity. This showis the individual variability of dopamine fluctuations.
Upon the empirical analysis of Edvard Munch's portraits (Bettelheim et al., 2024), the following results were found:

1. The contrast in his paintings increased during critical periods, aligning with vivid hallucinatory and delusional periods. His productivity also increased during these periods. Apart from the result of increased dopaminergic activity, this could have been a result of efforts to process and express intense emotions.
2. His magnocellular system was affected, which is typically seen in schizophrenia. This is evidenced by the lack of surrounding context, motion, or gesture in portraits. There is also no significant source of light and no shadows, This can indicate a lack of depth perception.
3. Edvard Munch seldom paints himself or others in a positive mood, consistent with the negative bias in facial emotion recognition received in studies of schizophrenia

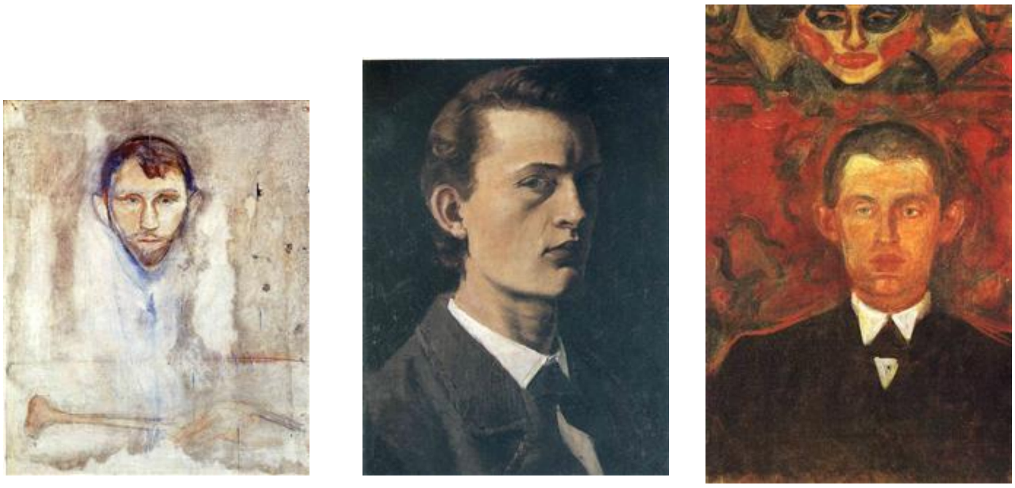
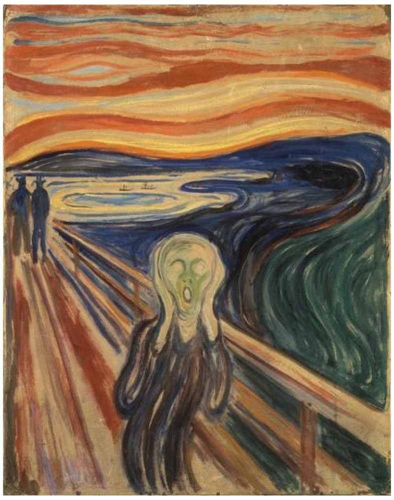


Figure VII: Portraits by Edvard Munch that emphasize his negative bias in facial emotion recognition and tendency to neglect surrounding context. In the right-most portrait, the background is rendered in less detail compared to the foreground, highlighting the impact that schizophrenia had on Edvard Munch's magnocellular system

Edvard Munch used deep, dark colors, such as red and blue, and somber tones in his artwork during the deterioration of his mental health. 'The Scream', created in 1893, would be a classic example of this. Post hospitalization and recovery, his paintings became free, fluid, and expressive, and he went on to create paintings such as "Winter, Kragero" which used lighter colors depicting a calmer setting. (Akiya, n.d.)
On the other hand, Vincent van Gogh's works became less colorful as his mental condition improved. "Shoes" is an example of a painting created a few years before the worsening of his illness and uses dull, muted colors such as brown and gray. "Starry Night", known for bright, vivid colors,was created during his severe manic episode in 1888.(Akiya, n.d.)
While artists had experienced a worsening in their mental state, their artistic expression varied tremendously. This could have been due to the nature of the disorder- while there is uncertainly surrounding the timeline of these artist's mental states and subsequent artistic output, it is possible that the manic episode that Van Gogh had experienced facilitated the production of bright, abstract patterns, whereas a depressive episode could have induced the changes in art style observed in Munch's work.

A similarity between “The Scream” and “Starry Night” is the flowing, continuous placement of analogous colors. While both pieces can evoke different emotions in the viewer, there is a notable resemblance in the technique used by both artists. This raises the question of why certain artists make these changes in their artistic style and output and highlights the need to understand the extent to which dopamine’s role in creativity and art style applies when it comes to these neurological disorders. Although it has been established that higher levels of dopamine activity increase levels of creativity, there is little research on whether or not the artwork created by these individuals could serve as a direct reflection of these changes in dopamine. This would allow us to better understand how neurological disorders impact everyday life and improve the quality of diagnosis and treatment for these disorders

Artist	Edvard Munch	Vincent van Gogh
Period of mental instability		

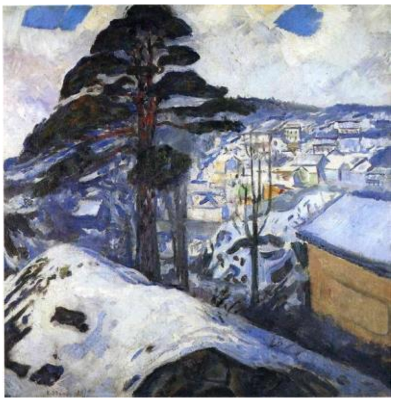
Period of mental stability		

Table IV: the paintings of Vincent van Gogh vs Edvard Munch in different mental states

III. LIMITATIONS

Art can be personal, instinctive, and emotional. Motivation, meaning, and technique display wide-ranging differences from person to person. As seen in this research, the causes of these variations can be broadly categorized as genetic or environmental. However, the intentions of artists making the choices and changes that they do can go beyond numerical measurements and predetermined personality traits.

The deep understanding and isolation of dopamine as a variable in this research plays an important role in comprehending the big picture of the innumerable factors that contribute towards the creation of art, and why these changes in art style occur. An activity as personal as the creation of art calls for in-depth, qualitative studies that are idiographic. Nomothetic approaches toward understanding the effects of dopamine are visual art that is useful for understanding general patterns and trends, but it is still crucial to understand the complex interactions that can occur between dopamine and other regions of the brain to avoid reductionism. This allows for a more comprehensive understanding of dopamine's interaction with other cognitive and emotional processes involved in the creation of art.

Louis Wain highlights the debate between the correlation and causation of mental illness and art style. He was famous for his consistent and unique depiction of cats throughout his career as an artist.

Upon his transfer to the Napsbury Hospital in St Albans in 1930, his artistic style transformed dramatically. While psychiatrists often point to the abstract patterns in his paintings as evidence of his schizophrenia, researchers have stated that there is no definitive timeline that has been established for the order in which his pieces were created, rather it has only been pieced together based on speculative assumptions. (Brenha & Teixeira, 2014; McGennis, 1999; *The Man Who Drew Cats: Louis Wain's Series of'Kaleidoscope Cats' Are Often Regarded as the Acme Of'asylum Art', but the Tendency to Pathologise His Drawings May …*, n.d.)

It is therefore difficult to pin his abstract and kaleidoscopic art style on the onset of schizophrenia. This example draws attention to the uncertainty that surrounds the disorders that these artists suffered from and their timelines, potentially impacting the validity of conclusions one makes on their personal experiences and artistic output.

Realistically drawn cat from early in Wain's career

Cat in psychedelic art style from later in Wain's career

Figure VIII: Evolution of Louis Wain's art style over time

Another limitation of this research is the number of neurological disorders that have been evaluated: dopamine impacts nearly every neurological disorder, which means that the conclusions drawn from this research may not be generalisable to all disorders that result in fluctuations in dopaminergic activity

V. CONCLUSION

Yayoi Kusama has referred to art as her medicine, and claimed that it has turned her psychological problems into art.(Gompertz, 2023) Although neurological disorders can be debilitating to those affected, evidence shows the potential they have, whether through the disorder itself or its treatment, to offer unexpected benefits in terms of creativity and expression, by igniting a passion for art, or amplifying existing talent and skill.

A majority of the results from the literature review point to high dopaminergic synthesis and activity as beneficial to the creation of visual art: Dopamine agonists can increase creativity and interest in art, hallucinations can lead to unique artistic concepts, amphetamines used to treat ADHD can induce creativity, and studies have also showed higher scores on creative thinking in BD patients. However, specific results also suggest that high levels of dopamine in the eye can lead to disorientation and overwhelm, and depressive episodes, associated with low dopaminergic activity, allow for higher executive function through a realistic evaluation of what can be accomplished in terms of artistic achievement. These exceptions raise doubts of the reasons why these potential drawbacks of dopaminergic activity are yet to be documented, and calls for research that aims to understand the same.

Future research should also investigate additional dopamine-related disorders such as OCD and anxiety, and consider a greater number of detailed qualitative case studies. This can help clarify the distinct effects of dopamine instead of other influencing factors and contextual variables.

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APPENDIX

Disorder	**Conditions**	**Effects on dopamine**	**Potential clinical expression**	**Effect of clinical expression on artistic output**
Parkinson's Disease	pre-medication	death of dopamine neurons in the striatum	decrease in divergent thinking	inability to think creatively
		low levels of dopamine in the basal ganglia	difficulty in initiating movement	less motivation to create art
		degeneration of mesolimbic dopamine	depressive symptoms	less motivation to create art, loss of pleasure while creating are
		reduced dopaminergic activity in the retina leading to cone-amacrine cell dysfunction	poor color vision, reduced sensitivity to contrast, loss of visual acuity	reflection of changes in perception in artwork, for e.g imprecise use of color in artwork
	post-medication	Increase in dopaminergic activity	insomnia	create art for large stretches of time
			increase in creativity	less precise but more vibrant and unique art stylee

			increase in motivation	increased productivity in artistic output
			increase in visual attention	
			increased novelty seeking	more likely to experiment with new art styles and techniques
			increased response to rewarding stimuli	addictive tendency towards creating and viewing art
			increase in motivated behaviors	higher chance of a PD patient taking up the task of creating art
schizophrenia	pre-medication	excess dopamine in the mesolimbic pathway	hallucinations	can inspire surrealistic art style
		elevated striatal dopamine synthesis activity, higher D2 receptors	increased divergent thinking	higher creativity
		reduced dopamine levels in the mesocortical pathway.	catatonia and avolition	reduced motivation and productivity
		reduced number of neurons in the visual cortex 1	stronger imagery	accurate recreation when replicating models in artwork
		abnormally large phasic dopamine response in the ventral striatum	stronger feeling of reward	addictive tendency towards creating and viewing art.
		retinal hyperdopaminergic activity	abnormal intensity of environmental stimuli	artwork consisting of many components and ideas that can come across as disorganized and overwhelming to neurotypicals
			inability to focus on specific elements of artwork	
			hyper-intense color perception	reflection of these changes in perception on artwork. For example, a schizophrenic experiencing these changes in visual perception can lead them to create artwork that has bright and vivid colors, instead of somber dull colors.
			increased brightness	
ADHD	pre-medication	Decreased D2 and D3 receptors in the accumbens and midbrain	inattention	inability to invest time into long-term art projects and difficulty focusing on tasks involving artistic output
			hypersensitivity toward environmental stimuli	predisposition for distraction during the art-making process. Hypersensitivity could also mean that the individual is more receptive towards the external environment, resulting

				in more detailed and sensitive
			reward-motivation deficits	slowed or difficult learning in motor skills and techniques that involve creating artwork
			decrease in ability to perform delayed gratification	inability to invest time into long-term art projects
		decreased activation in the ventral striatum	flattened response to rewarding stimuli	decreased interest in viewing and creating artwork.
	post medication	release of endogenous dopamine and activation od dopamine receptors	increase in energy	ability to create artwork for long periods of time, leading to increased productivity
			increase in creativity	less precise but more vibrant and unique art style
			hallucinations	an inspire surrealistic art style
			positive mood	depends on an individual's tonic dopamine levels:
Bipolar Disorder	Mania	increased dopaminergic drive	increased energy	ability to create artwork for long periods of time, leading to increased productivity
			rapid thoughts	could cause overwhelm and disorientation while creating artwork, or increased productivity due to quick idea generation and divergent thinking.
			hallucinations	can inspire a surrealistic art style
			high self esteem	can lead to openness, extraversion, lower inhibition, and novelty seeking (personality traits that lead to success as a visual artist)
	Depression	decreased dopaminergic drive	loss of pleasure	decreased pleasure derived from creating artwork
			indecisiveness	inability to make decisions regarding the composition, theme, medium, medium, etc when it comes to creating artwork. This could lead to lower productivity
			pessimistic assessment of what can be achieved	realistic deadlines and effective time management while creating artwork professionally