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The Never Ending Pursuit of Satisfaction: How the Brain Modulates Pleasure Seeking Behavior

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ABSTRACT

Humans are addicted to pursuing pleasure but are still unsatisfied. Dopamine modulates this activity. Mindfulness can help us do better as a society.

INTRODUCTION

As a society, we are compelled to pursue pleasure as easily and efficiently as possible. Nowadays, it seems like we often lose sight of the present moment, distracted by pursuits of worthless commodities and pleasurable experiences. These commodities however, are not invaluable in the eyes of a human. Nowadays modern society puts an emphasis on a consumerist lifestyle with overlooked addictive tendencies and new technology has only promoted pleasure seeking and indulgence while avoiding any kind of discomfort. Between social media, streaming software, and website browsing, humans are exposed to a multitude of advertisements promoting products, food, entertainment and more, begging to be bought, whispering about how good it'll make you feel. With new technology, money spending has never been so easy. Apps let you pick out your groceries online and have them delivered to your doorsteps. You can buy a completely new outfit within minutes and have it delivered the next day. Virtual games are constantly promoting a variety of money spending features.

Product purchasing, however, is not the only commodity current developments have brought forth. New technology normalizes consistent exposure to eroticism, whether that be through social media, pornography sites, or social apps where you can type a simple message and be sleeping with a complete stranger within a half hour. Where ten dollars can get you a personal erotic video chat and there are apps where you can swipe through an individual's nude pictures in order to decide whether they are "worthy enough" to send them a message introducing yourself.

Instead of spending time outdoors, getting the proper amount of sunlight, fresh air, and exercise, streaming software and video games have made entertainment so readily available that there is no longer a need to step outside of your house. It seems as if all of these inventions have been created to satisfy human desire with ease and to avoid any inconvenience by constructing the path of least resistance. As a society, we are addicted to the pursuit of pleasure and in moments where we need some type of gratification, or a quick pleasure fix, we can easily look to social media, pornography, streaming apps, drugs and alcohol, shopping, or food. The choices are endless.

We've built a civilization on the ease of pleasure seeking, but satisfaction is not as accessible. After you buy something, you're excited for about ten minutes, then the novelty wears off and it's common to wonder why you even wasted money in the first place. After having sex with a stranger we are left with intense feelings of loneliness and disappointment. People daydream about vacations for months, and while they are still fun, once on the vacation, it isn't anywhere close to as exciting or euphoric as you previously dreamt of/anticipated. Humans do all these things, yet still seem unsatisfied, still dreaming of their next achievement, their next vacation, the next show they are going to watch or the next purchase they are going to make. It seems that, as a society, we dream of satisfaction but never fully achieve it. There isn't as much time spent satisfied in the present moment because for every goal that has been met, humans are busy creating five more. I set out to find out the biological mechanism behind why human desire can never fully be satisfied, why we can never have enough or indulge enough in one way or another, and why desire/wanting is a fundamental aspect of life.

WANTING, PLEASURE, PURSUIT, SATISFACTION AND REINFORCEMENT

So what is enough for humans? What is the very mechanism of human desire and pursuit itself? Why do humans want? To want is to feel an innate sense of need for an object or thing that is lacking in abundance or existence. Wanting leads to pursuing and pursuing generally leads to a reward sensation. When we feel the sensation of needing or desiring something, we will generally move towards/pursue that need/reward. Similarly, when humans feel uncomfortable sensations, they will move towards the goal of reducing that uncomfort. Made famous by Sigmund Freud, the pain pleasure principle (Moccia et al., 2018) suggests that all humans are motivated to either avoid pain or seek pleasure. This can be observed in simple situations ie. feeling hungry, then pursuing the need (ie. going to the fridge, buying food, cooking, etc.) and satisfying the need by, for example, eating. This interaction between sensation, pursuit and satisfaction can also be observed in more complex, longstanding situations, like completing college or saving money, where the pursuit exists on a long term basis, over the span of a couple years but it still looks similar in this simple, fundamental model that emphasizes desire, pursuit, and satiation, where humans move towards pleasure or away from pain. Likewise, humans will also avoid any discomfort, uncertainty, or pain and the avoidance of this sensation is a reward in itself. Hunger is seen as an uncomfortable feeling, moving away from hunger by pursuing and eating food is also rewarding in that aspect. Wanting rewards is innate, seemingly a part of human and animal identity. People want what they want because in general, it feels good to get the things you want. We are involved in this lifelong pursuit of pleasure, almost always seeking, but many still live very unfulfilled lives, always ready for another pleasurable experience. Satiation, the sensation of being completely sufficient or satisfied by reaching a reward, seems to be both the most important and least important object in human perspective. We daydream about achieving our desires but when we finally do, we are often left feeling lost and confused, asking ourselves "now what?" and ready for a new pursuit and a new reward.

MECHANISMS OF PLEASURE PURSUIT

Popular culture has branded dopamine (DA) as the drug that's synonymous with reward, and while that is somewhat true, DA plays a larger role in movement rather than reward itself. As

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Doctor Robert Sapolsky once said, “dopamine is not about the pursuit of happiness, it is about the happiness of pursuit,” emphasizing how DA's role in this pleasure seeking, pain avoidance operation has more to do with orienting the body and brain towards reward, rather than actually feeling the sensation of pleasure itself. The brain regions active when doing pleasurable activities like eating, having sex, spending money, partaking in drugs, and reaching goals involve DA pathways that modulate human movement/motivation towards a reward and anticipated pleasure from future reward (Kenneth et al., 2018). Likewise, these same regions are active when a human avoids negative, painful, or uncomfortable feelings (Li et al., 2019). DA is a neurotransmitter and hormone that sends signals to and from structures in the brain and body that are responsible for a variety of different roles related to motor movement, memory, pleasure, reward, motivation, attention and more. Dysfunction in DA systems are involved with schizophrenia, behavioral disorders, movement disorders, addiction and mental health disorders (Badgaiyan & Wack, 2011) and each of these ailments can affect the ability to make healthy decisions, socialize, feel pleasure, move, or pursue pleasure.

Stimuli from the environment can excite midbrain DA neurons that are rooted in three different nuclei; the retrorubral area, ventral tegmental area, and the substantia nigra which are involved with learning, motivation, movement and reward associations (Luo & Huang, 2016). Mesolimbic and mesocortical pathways project dopamine from the VTA to the nucleus accumbens (NAc) and the prefrontal cortex (PFC) (Luo & Huang, 2016), with the nucleus accumbens linking reward behavior in the executive and limbic systems, integrating information from both executive function from cortical areas, as well as immediate emotion and sensory information from the limbic system, directing goal behavior, motivation, and learning. Cortical areas are associated with higher order functioning (Mercadante & Tadi, 2022). The cortex consists of the four main lobes (pituitary, frontal, occipital, temporal) that each take information from a multitude of brain structures and process/make sense of it simultaneously in order to create a higher model of the self and perceive the world efficiently. These areas play a role in more complex functioning like awareness, thought, memory, attention, consciousness, advanced motor function and language (Javed et al., 2021) while the limbic brain is more or less the “lizard brain,” playing a role in bottom up processing and almost subconscious or immediate emotion and sensation. The limbic system is more or less the structures receiving the pure sensory information we are getting from our internal and external environment without organization and higher order function from the cortex. As a bridge between these two brain systems, the NAc can take feelings of desire from the limbic system, send information to the cortex, and the brain and body will assign meaning to that feeling. Executive control and limbic activity are modulated by medial prefrontal cortex (MPFC) and ventral striatum (NAc) and dorsolateral prefrontal cortex (DLPFC) and dorsal striatum (Hanlon et al., 2015).

Likewise, the hippocampus (HC) also works closely with the NAC, supplying it with relevant information for motivational behavior (Gruber et al., 2009). The HC plays an active role in memory storage and retrieval, making it an important aspect of reward memory, learning and experience. The hippocampus is most commonly known as the “memory structure” of the brain. Memory, cognition, and sensation all work together to create the most efficient model of the environment. Humans and other organisms can identify past relevant experiences from hippocampal information and use that knowledge to take appropriate action. Associations between the DA network and HC are crucial for learning about the environment and what behavior can lead to what outcome. The HC is part of the limbic system, where DA is projected to it via the VTA pathways (Kempadoo et al., 2016) and also from the striatum or NAc (Abela et al., 2015). When lesioning the nucleus accumbens in mice the result is impaired, irrational and impulsive decision making (Cardinal & Howes, 2005). Without this link, an individual would have trouble connecting dopaminergic sensation to meaningful experiences.

Furthermore DA projections from the substantia nigra to the dorsal striatum regulate movement through the nigrostriatal pathway and basal ganglia motor loops, (Luo & Huang, 2016) regulating another important role of dopaminergic firing, the ability to propel movement towards specific circumstances. These regions are able to modulate energy expenditure via movement, where a higher rate of dopamine firing elicits more energy expenditure and lower dopamine activity promotes energy conservation (Beeler et al., 2012) meaning the more electrical signaling of DA, the more an organism is willing to move towards a goal. Dopamine firing is both tonic and phasic following stimuli. Tonic firing involves slow steady action potentials over a longer duration of time while phasic firing involves more intense action potentials over a shorter period of time. (Klanker et al., 2015) High tonic dopamine release in the ventral and dorsal striatum elicits higher energy expenditure, even if faced with lower value rewards (Gepshtein et al., 2014) while the contrast is true for lower rates of tonic release per what (Beeler et al., 2012) demonstrated. (Gepshtein et al., 2014) discusses how tonic dopamine release is important for a “background” or supply of dopamine in the cells and is more movement related while phasic DA release is associated with unexpected reward and prediction of future reward. (Lamichhane et al., 2022) displayed a kind of ramping up behavior or quick increase of activity in the ventromedial PFC activity as the brain predicted a reward that is most likely the result of phasic DA in the midbrain nuclei. These phasic dopamine release schedules are responsible for the exciting anticipatory phase leading up to a reward and play a huge role in the learning aspects of dopamine behavior. When an unexpected reward is presented, phasic dopamine release in the midbrain encodes for a positive prediction error where dopamine activity spikes to above baseline, when a reward is expected, dopamine levels increase to account for the anticipation but remain relatively the same when the reward is presented, and when a reward is less then what is being predicted, dopamine levels fall to below baseline (Schultz, 2016), playing a large role in the learning process of dopamine. This is what lets the brain remember positive reward experiences and negative reward experiences for future reference. If the brain anticipates a reward, but the reward ends up being less than what was predicted, information from this experience can be consolidated into memories affecting future action when presented with similar circumstances. The hippocampus works closely with the motivational system associating memory and learning experiences with positive and negative stimuli. The VTA, which encodes for reward prediction error (Solié et al., 2021), releases DA to the dorsal hippocampus, promoting learning experiences in pleasure seeking behavior (Kempadoo et al., 2016). All these systems work together to form an understanding of how an organism should interact with the world around itself, optimizing the ability to navigate through life.

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Reward from pleasurable experiences is thought to be divided into two separate categories; primary and secondary reinforcers. Primary reinforcers exist on a more biological basis ie. sex to reproduce, food and water to stay alive, shelter to protect themselves. Secondary reinforcers can be seen in more established societies, where threats like predators, environmental conditions, and food sparsity is not as innate (Delgado et al., 2011). Secondary reinforcers are based on biological survival motivators, but will not necessarily lead to death. Money is an example of a secondary reinforcer, where lacking it doesn't necessarily mean immediate extinction, but it does make obtaining necessary resources either more or less accessible. Money in itself, as a piece of green paper will not increase the fitness of an organism, but still provides a feeling of reward because it increases the availability of primary reinforcers. Humans and animals can be reinforced by any object or concept that stimulates dopamine and or pleasure feelings. Humans don't go to work everyday because they want money for the mere sake of having a green piece of paper, they go to work because having money means you have more access to not only the thing you need to survive, but also to things that bring you pleasure.

EVOLUTION OF REWARD PURSUIT AND DOPAMINERGIC PATHWAYS

To help us understand human reward, pleasure and motivation/pursuit, we must first consider the basics of evolution. The Theory of Evolution is the process by which organisms adapt, change, and variate throughout generations. The theory of evolution illustrates the process by which a species's individual traits evolve over time based on their ability to survive in and adapt to the environment surrounding an organism. An organism with unfavorable traits may not survive or thrive in certain environments in turn inhibiting those traits from being passed down to offspring, whether that be because the organism died or could not mate, eventually causing these traits to disappear or be significantly reduced in a population. A trait that minimizes the chance of an organism surviving, like a bunny having brown fur in a snowy environment, will not be passed down to offspring because the brown bunnies will likely not survive when faced with predators, while the white bunnies thrive and continue to reproduce. Any trait that increases the amount of babies an organism has, and the likelihood that it will survive, will be more likely to be passed down through generations. When looking at evolution in pleasure seeking pathways, there is evidence that, although there are downfalls, pleasure seeking is a favorable trait for survival. Not only is pleasure seeking about feeling good, it's about the motivation to move towards a goal. Life needs a mechanism to move. With no goal to move toward, an organism would be stagnant, not concerned about food, water, or reproduction, basically dying. You can infer that motivation, moving towards a goal, and pursuing is an important trait that contributes to a species fitness because it still exists, and was not weeded out through evolution. Likewise, all animals seem to have some kind of similar motivation system (Berridge & Kringlebach, 2008) displaying that a motivational system is necessary for survival and evolution. In humans and some other animals, dopamine plays the main role in pleasure seeking activities like sex, eating, shopping, exploration and social activities and through long term evolution, dopamine has become "the drug" that makes humans and other animals feel good while executing these activities. Dopamine activity is the regulatory mechanism for pleasure driven, yet instinctual activities like sex, eating, and resource collecting, that increase the likelihood that an individual organism will survive and reproduce (Loonen & Ivanova, 2017).

It is also important to note that DA activity results in more complex activity besides feeling good while pursuing mating or eating behaviors. Without a healthy DA system, organisms cannot make proper decisions, move towards those decisions, learn from positive and negative reinforcement and in turn, possibly reducing the fitness of that organism.

Social behavior is an example of an instinctual, pleasurable experience that holds evolutionary value. There is also evidence that social interaction, another somewhat enjoyable activity, is modulated or influenced by dopamine (Jansen et al., 2024). Social interaction in different organisms is adaptively significant, playing a large role in the behavior and survival of a species (Blumstein et al., 2010). Social behavior can increase an organism's ability to survive through mating and reproduction, or through the avoidance of predators. Cooperation, coliving, kin selection and more are all examples of species other than humans participating in social hierarchies. Social behavior is key to the fitness of a species, especially humans, who lack the physical qualities of wild predators. A single human would have a difficult time surviving alone, but a whole tribe can help each other ensure safe environments, reproduce, and collect resources. An important aspect of natural selection that can be viewed from a social perspective is reproduction. The nigrostriatal pathway plays a role in sexual motor control and the mesolimbic and mesocortical dopamine pathways play a role in the anticipatory behavior leading up to sex (Melis et al., 2022). Hypersexual behavior has been observed in cases of Parkinson's Disease treatment, which directly involves movement and reward pathways (Fong, 2019), showing that DA activity plays an important role in managing this instinctual behavior. Because sexual behavior is partially rooted in dopaminergic activity, if an organism has more efficient or higher levels of motivational processing, it may be motivated to engage in more sex, in turn having more offspring and passing down the traits that encode for higher levels of dopamine activity, increasing the fitness of species. Natural selection favors the traits that aid in survival likelihood and offspring production. Interestingly enough, there is a correlation between males that have the DAT1 gene, a dopamine transporter gene, and the number of sexual partners they have (Guo et al., 2007), however, there were no significant findings for females in this study. There is also evidence that dopamine agonists, like amphetamines, stimulate sexual behavior (Zemishlany, 2010) showing that sex is primarily a pleasure driven behavior. Dysfunctional sexual behavior can be the result of a malfunction in the DA pathways. Depression, which is characterized by anhedonia or the lack of pleasure, is associated with a dysregulated DA system. Typically, in cases of depression, there is a lack of motivation to do pleasurable activities, like engage in sexual behavior, or pursue potential romantic partners showing that although these behaviors may not be primary reinforcers for humans anymore, there is still a deep instinctual value to them.

Furthermore, in the case of instinctual drive in humans today, resource collecting and food behavior is also heavily dictated by DA systems. According to natural selection, if an organism is motivated to pursue more resources, like food and shelter, it will be more likely to survive and more likely to have babies, increasing the number of offspring with better pursuit systems. Binge eating is an example of how instinctual motives can become dysregulated through food reinforcement. Binge eating is associated with altered dopamine behavior compared to baseline or "normal" activity (Yu et al., 2022) and in conditions like ADHD, where dopamine systems

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aren't regulated, eating can be stimulating for an individual (*Brain Reward Response Linked to Binge Eating and ADHD*, n.d.). Furthermore, overconsumption of food can impair cognitive control, possibly because large amounts of DA stimulation drive reward seeking and instant reward behavior (Mattson, 2019). Resource collecting, whether that be collecting food or other objects can also be very stimulating and many animals other than humans are rewarded by foraging and seeking behaviors (Barron et al., 2010). Nowadays, when shopping, an individual may notice how the anticipation of a reward may feel exciting and euphoric but when the reward is actually achieved it may not feel so fun, new, or exciting. Shopping stimulates DA activity similarly to DA agonists and can be even considered an addiction in some individuals (Hartston, 2012). There is often a period after shopping where the novelty wears off and an individual is left feeling uncomfortable about the amount of money they spent, or the items they bought but didn't need. This could be for a multitude of reasons but it's important to note that DA activity is not responsible for the pleasure of having things, it's about the pleasure of perceiving that you will have something pleasurable. Shopping is pleasurable because human brains predict that having the object you want will be a pleasurable feeling in itself, and when that object is finally presented, DA levels fall back to baseline according to reward prediction.

From an evolutionary perspective, it's also important to note that lesions in the mesolimbic dopamine pathway stop novel exploration in mice (Wahlstrom et al., 2010) displaying that novelty seeking is another dopaminergic activity that most likely played a role in the fitness of organisms, resulting in the reward feeling that it is associated with today. Novelty seeking is the concept of seeking new, unfamiliar and unknown experiences and dopamine is thought to prompt this exploration behavior (Costa et al., 2014). Novel experiences are generally enjoyable and novelty seeking is displayed in various different forms such as eroticism, travel, exploration, and more. Novelty behavior is important for information acquiry (Costa et al., 2014) and in turn, can aid to the fitness of a species because seeking new experiences can motivate an organism to seek more mates and explore an environment or object more thoroughly, possibly resulting in more resources or more information. Novelty plays a huge role in most pleasure seeking activities that humans enjoy today. (Yuan et al., 2011) found that the DRD4 dopamine receptor, which plays a role in novelty and pleasure seeking, differs in Asian populations versus Americans. Americans more often have the gene that is associated with hyperactivity and novel seeking. This could explain why the individuals with the novelty seeking gene left Asia, but the ones that didn't have it stayed. It could also explain cultural differences between the Americas and Asia. In western culture oftentimes the mundane, day to day lives of humans slow down and lose novelty, demanding more excitement. Humans feel and respond to this lull in a multitude of ways. Some people vacation, others try new activities on the weekends, some people will look for a new partner and other people will try using recreational drugs to stimulate the dopamine activity in their brains. Humans like trying new things because it's rewarding.

REWARD CONDITIONING AND LEARNING

Thorndike's Law of Effect emphasizes that reinforcement of a behavior will increase the said behavior (Athalye et al., 2018), for example, in operant conditioning, if a dog is rewarded with a treat every time it shakes its paw, the frequency of paw shaking will increase. If a cat is rewarded with food everytime it meows too much, vocalizing its hunger will increase. Organisms are constantly learning and changing based on the environment, experience, and prediction. Organisms are also adapting to both positive and negative reinforcement. The hippocampus, or memory center of the brain, can consolidate memories based on reinforcement, meaning your brain will remember when it is rewarded or punished from an action. Because the NAc works closely with the HC, the brain can take information from a negative or positive stimulus and its response, and consolidate that experience into a memory. This memory can be used in future instances, where the brain is faced with a choice on how to orient itself. For example, if you die taking a specific path in a video game your brain will remember the frustration you felt and associate it with this path, making you less likely to want to re-experience this part of the video game. Likewise, if you find cool rocks when you take a certain route to school, you may be more likely to take that route because of the positive experience you associate with it. Humans and other organisms are conditioned to seek pleasure because when they do, usually, they are rewarded from it. Reward conditioning has huge implications regarding learning.

DA is responsible for the excitement and euphoria during the pursuit of pleasure rather than the pleasure itself being experienced. This explains why imagining/daydreaming of an outcome or being highly motivated to reach a goal may feel more emotionally profound and vivid than actually reaching the reward, or having the imagined thing. Affective forecasting, also known as hedonic forecasting, is the predicting of one's own feelings and emotions when faced with specific circumstances in the future (Zanna, 1992). People will generally be able to predict whether they will feel good or bad in a scenario, but tend to overestimate the influence the specific emotion will have on their lives, overestimating the duration and the intensity of the specific feeling (Zanna, 1992).

Reinforcement of a reward continues reward behavior, potentially even increasing the frequency of the behavior, but why doesn't the behavior always feel as good as we predict it will? (Eshel et al., 2023) states that "dopamine is for wanting and seeking, but not liking and having" and in an experiment, displays in mice that the higher the motivation it had, the lower the dopaminergic related reward is. In other words, dopamine is a regulatory mechanism that makes the pursuit of pleasure feel good, and once the pleasure is achieved, the brain no longer needs a mechanism that drives an organism towards that reward, explaining why humans may feel "lost" or unmotivated after attaining their goals or attaining pleasure. This could explain why after binge eating people report feeling disappointed in themselves, or after hookups people report feeling wrong. Dopamine may drive those activities, but is depleted back to baseline after the pleasure threshold is crossed (Schultz, 2016). (Lamichhane et al., 2022) shows evidence of a fast paced, sharp increase of activity or "ramping up" in the ventromedial PFC as an individual predicts a reward. The activity in this brain region increases up until the moment the reward is fulfilled, then the activity decreases again, likewise (Klanker et al., 2015) displayed phasic dopamine activity (quick, strong signals) occurring when rats were given a cue that they were previously conditioned to associate with reward but not when the actual reward was presented to them, thus showing that DA is not associated with actual pleasure feelings from the reward itself, and depletes quickly once the predicted reward is actually presented. The actual feeling of pleasure itself, like food tasting good, the pleasure feelings from orgasm, or laughter with your group of

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friends is associated with other neurotransmitters like oxytocin and serotonin (Coria-Avila et al., 2016) more than dopamine but dopamine is the driver of the pursuit of these pleasures.

Organisms are constantly adapting and changing in response to environmental conditions and the reward prediction model modulates pursuit and satiation behavior. The brain displays increased dopamine activity when an unexpected reward is presented, possibly because this behavior gave the organism information that is vital to pursuing future rewards. Connections between the VTA and hippocampus suggest that pursuing a reward, and whether or not an organism gets the reward facilitates learning. Dopamine activity does not increase when a predicted reward is experienced (Schultz, 2016), possibly because this behavior is already a learned behavior that results in pleasure, when the VTA DA activity spikes, there are projections to the hippocampus, possibly to form connections between a novel behavior and/or a novel reward. Satiation begins and pursuit ends when predicted reward is not lining up with actual reward, depressing dopaminergic activity.

COST REWARD EVALUATION AND COGNITIVE CONTROL

Another important function of the motivation and reward system is the ability to evaluate cost and reward. Cost entails the potential implication of a behavior like danger, missed opportunities, effort (physical and mental) time and discomfort (Simpson & Balsam, 2016), while reward entails the possible benefits. As discussed, dopamine is the reinforcer that drives motivation, but it also plays an intelligent role evaluating pursuit and energy expenditure in order to maximize the odds of survival. Dopamine in the striatum relates to cost and reward evaluation, and adapts to environmental factors to maintain a healthy energy balance and direct an organism's energy balance the most efficiently (Beeler et al., 2012). Activity in the NAc, the structure that integrates both mesocortical and mesolimbic pathways, also modulates cost and energy balance. Organisms are generally biased to prefer lower-cost, smaller rewards rather than high cost, larger rewards because it is safer to do so (Eshel et al., 2023). This behavior is important in decision making in both humans and animals, because it creates a healthy decision making model and influences where humans direct their desire based on possible outcomes.

Moreover, cost-reward evaluation can exhibit a degree of cognitive control, an important function of the motivation system. The mesolimbic and mesocortical pathways meet at the NAc where feelings of desire meet the both driving and inhibitory effects of the prefrontal cortex. As discussed earlier, organisms are generally biased to choose a smaller, easier to obtain reward. When humans are presented with the choice between a small reward now or a larger reward much later in time, they tend to prefer the smaller reward, and even when the large reward is chosen, it loses some of its value due to the wait time (Myerson & Green, 1995). This shows that dopamine related mental processing isn't good at predicting the future very well. Future prediction is more associated with self control than impulsivity, being modulated by cognitive control. It makes it seem like dopamine is about finding the most instant or immediate rewards. The marker of reaching large, long term goals, or delaying gratification is based on how much cognitive control you exert over a reward pursuit instinct. Those with less cognitive control may make more impulsive, quicker decisions that are aimed towards more instant gratification because that's what life is biased towards.

There is also evidence that higher drives for desire, or a higher motivational state is correlated with dissociated cognitive control (Lamichhane et al., 2022). The prefrontal cortex and other frontal regions play an important, executive role in decision making (Gruber et al., 2009), taking information from other lower level structures in the brain, and combining this information to form meaning from an experience. Forming meaning in this scenario, dictates the brain's ability to decide what it wants to do when presented with stimuli. (Lamichhane et al., 2022) illustrates the dissociation of cognitive control when participants in a study made impulsive decisions. The results of this study displayed how cortical region activity reflected the self control of a participant when faced with a potential reward. Cognitive control and delayed/ instant gratification and biased to conserve energy.

Humans go through life, with their perceptions guided by a push pull, but complementary relationship between limbic arousal and executive control, by bottom up sensation and top down organization. The limbic arousal being associated with the raw sensory input from the environment, the raw stimuli and the raw reaction to that stimuli while the executive system is responsible for organizing this information and processing it into a meaningful experience, making sense of the experience being had. When presented with a choice, humans will generally choose the most cost efficient, convenient reward (Lamichhane et al., 2022), with limbic and executive regions reflecting that choice. There isn't much evidence of dopamine's ability to inhibit or affect neuronal activity associated with cognitive control, but we often see decreased cortical-frontal/executive region activity in cases of motivational dysregulation when individuals make impulsive decisions, and especially in cases like ADHD or addiction (Brockett et al., 2018). In choices between reward now or reward later, humans will generally choose the reward available to them quicker, and there is evidence that the degree of self control in this scenario is somewhat modulated by frontal-parietal areas.

DISCUSSION

So I ask again, why do humans never have enough? Why are we where we are? Why is this the state of the world today? New technology has promoted pleasure seeking and indulgence while avoiding any kind of discomfort. Why are humans so indulgent? To start off, humans are biased towards convenience. We want whatever feels good at the lowest cost. We spoke of the evolutionary value of this trait and how it is to maximize energy efficiency. This trait is neither negative nor positive in the span of things, just different. A starving cat will generally be biased to eat the kibble offered to it instead of spending its energy hunting for prey that is not a guarantee. Human bias towards convenience can be looked at similarly. Why spend money, time, and resources to go out and make friends in order to fulfill the need for social gratification instead of spending time online, from the comfort of your house, which doesn't necessarily cost as much money or take as much energy but still satisfies the desire. Granted, many individuals do spend social time away from their phones, but social media and messaging apps are changing aspects of social behavior norms quickly.

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New technology is created to solve problems, so although there is a discussion about the downfalls of these new ideas, there are very many positive discoveries associated with technology. Phones made long term relationships possible, dishwashers changed the world, WiFi makes checking your bank account easier, and cars make getting from point A to B faster. Technology was created to make life easier, and in some sense, this can be an amazing tool but I am proposing that technological advancement displays a changing "normal" in societies where tasks, even enjoyable ones, are getting easier and easier promoting indulgence and instantly gratifying behavior. It seems like nothing will be too convenient for humans because we still hold the same evolutionary dopamine traits. We still want to yield the most reward with the least expenditure. Humans still seek pleasure similar to an animal, it is just modernized through technological advancements. We are still driven by sex, food, and material things, it just gets more complex as the brain evolves. The cost-reward paradox emphasizes that humans will always try to solve problems more efficiently and create more convenient ways to function in order to reduce costs, and we see this through technological advancements. Human innovation is astonishing but there are many downfalls to it as well regarding the pleasure seeking aspect. In a convenient, pleasure seeking, indulgent society, humans are always anticipating the next best thing, biased towards instant gratification because it costs less. It seems as if we've become lazy because we're surrounded by so much convenience.

The interplay between cognitive control and immediate sensation play a huge role in current society's motivational issues. The limbic system might be alerted to hunger sensations, and make you want to stop at McDonald's or the next fast food restaurant on your way home from work but a higher degree of cognitive or self control might keep you on the road because you don't have the money or blood pressure to eat food from the fryer. Likewise, when you are on your phone scrolling through 15 second tik tok videos, the voice in your head telling you that you need to get off your phone and do laundry or work on assignments is most likely the cognitive control aspect of your brain, but when it feels impossible to put your phone down, it's because your PFC activity isn't strong enough to override the pleasure seeking experience (Latzman et al., 2015). Most of society is addicted to some kind of stimulating behavior, whether that be drugs, sex, gambling, eating or simply scrolling on their phones. This could be the result of instant pleasure being so easily attainable that humans are biased to expedite any possible pleasurable experience. If there's a possibility to pursue any kind of gratifying stimuli, humans seem biased to move towards it. Thorndike's Law of Effect discusses how reward conditions and promotes reward pursuit if the cost is low enough and the reward is high enough (Athalye et al., 2018). For example, the bag of chips sitting next to me is subconsciously teaching my brain that in order to achieve the pleasure of eating I don't need to plant a garden that yields veggies, waste time cooking in the kitchen, or use my energy to cook or garden, I can just pick up some chips from the store, or even order food with DoorDash. If I want to procreate with a male, it's easier now than ever. I don't have to spend time and energy to go on a date, I can use an app on my phone and LITERALLY swipe through pictures until I find a man I prefer. If I want to entertain myself while bored, I can turn on my TV or scroll through Instagram instead of spending time outdoors or spending time being creative. Making art, dating, and cooking can all be rewarding events and many humans still participate in these activities willingly but sometimes these behaviors are more costly, and at times, when DA activity is low, organisms might be biased to conserve energy in any way possible.

In the face of technology, humans seem to be conditioning themselves to delay gratification less. If there are low levels of DA firing, they can still pursue rewards because we have created mechanisms to assist in the pursuit of pleasure. There are bars, drive throughs, hookup apps, and cars that assist humans with energy conservation while still seeking pleasure.
Why wouldn't humans be biased to use these things? Especially if they are getting conditioned to use these mechanisms because using them means a more efficient reward pursuit.

Instant gratification is associated with less cognitive control and after prior exertion of self control, the DLPFC activity decreases even more than it did in the first instance (Hedgcock et al., 2012). This could be tied back to the cost reward complex, where more DA activity means more energy expenditure and impulsivity and where DA levels are depleted after reaching a predicted or less than predicted reward could mean less self control. This could explain activities like doom scrolling and compulsive phone activity, which is mentally stimulating and also which provides a socially gratifying space. Social behavior is rewarding due to its evolutionary value. Because this behavior feels so rewarding we continue to scroll until we find a post or a video we like, even though we know we could be doing something more productive. This is probably modulated by instant gratification behavior, where we exude less cognitive control when faced with a reward now option.

Dysfunction in DA systems is associated with recreational drug usage, schizophrenia, parkinsons, ADHD, depression and other mental and physical health issues (Grace, 2016). (Eshel et al., 2023) found that in addictive states, DA release is both sensitized and depleted, meaning that DA firing can be depleted after consistently high rates of firing, and also sensitive to stimulating activity. In instances like amphetamine addiction, DA firing intensity and rate increase after ingesting a stimulant the first time. As a person continues to use a stimulant, dopamine receptor expression decreases in response to high levels of stimulation (Wise & Robble, 2020), making it more difficult to reach a baseline state. A consequence of drug induced motivation dysregulation is decreased cortical inhibitory control, leading to more impulsivity and irrational decision making (Meyer et al., 2015). Likewise ADHD is associated with the DRD2 allele that prevents normal DA receptor formation (Oscar Berman et al., 2008). ADHD is associated with impulsivity and an increased risk for addiction disorders (Davis et al., 2015), displaying that dysregulation of DA systems deteriorates the ability to navigate in this world efficiently, possibly distorting higher order functioning. In both addiction and ADHD behaviors are associated with a loss of self control. If something like shopping cna become psychologically addicting, couldn't compulsive phone usage or compulsive pleasure seeking also have similar addictive tendencies? Although using your phone is not as strong as stimulant usage, there could be some potential motivational side effects from it from an addiction perspective. (Fernandez, 2022) discusses how over a long period of time, users of social media and other technology can cause DA deficits, almost building up a "tolerance" and more stimulation will be needed to reach the same gratifying effect as before. Couldn't this be said about all pleasure seeking? If we live in a society that prioritizes pleasure seeking, where our DA is being constantly stimulated, won't

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our species eventually need to create more stimulating, low cost, and more convenient inventions to gratify humans? Will humans ever be satisfied? Our dopaminergic systems aren't evolved to make us feel complete satisfaction, they are evolved to propel us towards pursuit so that we can survive.

The bottom line is humans struggle to have enough because life isn't about pleasure, or pursuing it correctly but that is often forgotten when most of society lives in addictive mindsets, addicted to phones, drugs, sex, eating, exercise, social gratification etc. It seems like humans aren't even addicted to things as much as they are addicted to finding pleasure through whatever means possible. Life isn't about satisfaction, rather, satisfaction is a byproduct of evolution. But as humans, with brains that evolved to survive based on pleasure seeking, we forget that. We often get caught up identifying with what our brain wants rather than what is actually necessary in the present moment. Humans equate happiness with pleasure or having things (that aren't always physical) and while that isn't a bad trait, if you ask anyone what their goals are, it's generally to do what they want to do. While this innate "wanting" can lead people to make great strides in their field of choice, or experience the magic of creating life, reaching a want will never be as satisfactory as you imagine it will be because if it was, we would have no need to keep evolving or keep moving forward. We would have no mechanism that keeps us wanting more and become completely stagnant. (Szczypka et al., 2001) discovered that dopamine deficient mice will die of starvation within a month, but when L-DOPA was administered, feeding behaviors were reversed. These mice lacked the motivation and the biological promoter to pursue necessary resources for survival. Without a regulatory mechanism, they were not able to identify and pursue goals. We think "once I have enough money I will finally be happy" or "once I have kids I will be satisfied with my life" but having doesn't necessarily correlate with happiness. Money is the thing that most people are driven by, largely because it makes pursuing rewards more accessible, and money is associated with life satisfaction, but only to a small extent, capping somewhere around six figures (Berger, 2023). Most people can't feel more happiness than others, as it is only a temporary state but many humans believe that billionaires and celebrities are happier than them because they have the ability to do whatever they want. But doing whatever you want is not correlated with happiness, reward prediction error proving that. Most things that you want to pursue are only associated with slight increases of DA, but after reaching a goal, DA levels fall again.

SOLUTIONS AND IMPLICATIONS

Some individual brains may have an easier time regulating their motivational systems than others. Those with ADHD, schizophrenia or genetics associated with addiction might fall into the cycle of pleasure seeking and decreased cognitive control more easily but all people struggle with pleasure seeking and instant gratification to some extent. In normal, day-to-day functioning, the push pull relationship between the limbic system and executive system plays a large role in perception and healthy decision making. The limbic system and bottom up signals are responsible for feelings of impulsivity while cortical regions modulate that sensitivity, often considered the "higher order" function of the brain. When these two regions are working together harmoniously, we get normal experience in our environment, however, when an individual experiences high levels of stress, the ability to navigate life gets more difficult.

Acute and chronic stress can weaken the control of the prefrontal cortex while increasing the impact of stimuli in our sensory areas (Arnsten et al., 2015). High levels of stress hormones temporarily inhibit or greatly reduce the higher order function of the brain, possibly so humans and other animals can act quickly in response to dangerous stimuli. Furthermore, addiction is the most prevalent in groups with adverse/stressful life experiences (Harline, 2015), displaying the lack of cognitive control in the face of stress. Less cognitive control means that an individual will make quicker, impulsive, and irrational decisions. Managing your stress is important to reduce pleasure seeking habits. High amounts of stress weaken the top down function of the brain, letting the sensory areas run rampant. Any sensation you have in a sympathetic state may be acted upon quickly, without thought from your higher order regions. I would argue that most of the population is stressed out and traumatized, possibly explaining the large need for pleasure seeking in our society.

Luckily, the brain is adaptive and much of the damage we do to it can be improved. The brain is forever learning and with some practice, you can increase your self control, discipline, and overall life satisfaction. Developing healthy habits like working out, eating a well balanced diet, and maintaining a social life are always beneficial and can increase the ability of the hippocampus and the working memory (*Brain Recovery after Alcohol and Other Drug Use - Alcohol and Drug Foundation*, 2022) by consolidating new, pleasurable, yet healthy experiences.

Self control after prior exertion comes less easily. In the short term, this means we can "run out" of self control, however, you have the ability to strengthen your cognitive control long term by practicing. (Muraven et al., 1999) present evidence of self control ability increasing following practice. This study found that individuals who had practiced unrelated self control exertion over smaller tasks did better when trying to override physical discomfort in the study. This means that if you are trying to use your phone less or save money, practicing any kind of self control can increase cognitive ability.

One final possible solution to a pleasure seeking society is practicing mindfulness. Mindfulness is an efficient stress reduction technique that can also help with addiction recovery (Bidlingmaier et al., 2022). It consists of meditation and controlled breathing to enhance consciousness and awareness. This practice can enhance top down activity and self control (Quaglia et al., 2019) by increasing the connectivity between the amygdala/sensory regions and the prefrontal cortex, giving an individual a more accurate ability to self monitor (Kral et al., 2018).

CONCLUSION

It seems as if our brains will be biased to seek pleasure until our pleasure addiction becomes disadvantageous for survival. While having goals is important, true life satisfaction has nothing

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to do with our pursuits and motivation. Humans will always be slaves to their DA activity. This can result in amazing discoveries and relationships but we are always going to want something. Humans will never be satisfied based on achieving their wants because our brains aren't wired to do that. Satisfaction is accepting the present moment as it is, as the stillness between avoidance and pursuit.

REFERENCES

Abela, A. R., Duan, Y., & Chudasama, Y. (2015). Hippocampal interplay with the nucleus accumbens is critical for decisions about time. *European Journal of Neuroscience*, *42*(5), 2224–2233. https://doi.org/10.1111/ejn.13009

Arnsten, A. F. T., Raskind, M. A., Taylor, F. B., & Connor, D. F. (2015). The effects of stress exposure on prefrontal cortex: Translating basic research into successful treatments for post-traumatic stress disorder. *Neurobiology of Stress*, *1*(1), 89–99. https://doi.org/10.1016/j.ynstr.2014.10.002

Athalye, V. R., Santos, F. J., Carmena, J. M., & Costa, R. M. (2018). Evidence for a neural law of effect. *Science*, *359*(6379), 1024–1029. https://doi.org/10.1126/science.aao6058

Badgaiyan, R. D., & Wack, D. (2011). Evidence of Dopaminergic Processing of Executive Inhibition. *PLoS ONE*, *6*(12), e28075. https://doi.org/10.1371/journal.pone.0028075

Beeler, J. A., Frazier, C. R. M., & Zhuang, X. (2012). Putting desire on a budget: dopamine and energy expenditure, reconciling reward and resources. *Frontiers in Integrative Neuroscience*, *6*. https://doi.org/10.3389/fnint.2012.00049

Berger, M. W. (2023, March 28). *Does Money Buy Happiness? Here's What the Research Says*. Knowledge at Wharton. https://knowledge.wharton.upenn.edu/article/does-money-buy-happiness-heres-what-theresearch-says/#:~:text=Specifically%2C%20for%20the%20least%20happy

Berridge, K. C., & Kringelbach, M. L. (2008). Affective neuroscience of pleasure: reward in humans and animals. *Psychopharmacology*, *199*(3), 457–480. https://doi.org/10.1007/s00213-008-1099-6

Biedlingmaier, A. J., Yovankin, T. G., Koola, M. M., Yanuck, M., & Varghese, S. P. (2022). An Overview of Mindfulness-Oriented Addiction and Pain Recovery. *Journal of Nervous & Mental Disease*, *210*(10), 808–810. https://doi.org/10.1097/nmd.0000000000001497

Blum, K., Gondré-Lewis, M., Steinberg, B., Elman, I., Baron, D., J Modestino, E., D Badgaiyan, R., & S Gold, M. (2018). Our evolved unique pleasure circuit makes humans different from apes: Reconsideration of data derived from animal studies. *Journal of Systems and Integrative Neuroscience*, *4*(1). https://doi.org/10.15761/jsin.1000191

Blumstein, D. T. (2010). Towards an integrative understanding of social behavior: new models and new opportunities. *Frontiers in Behavioral Neuroscience*. https://doi.org/10.3389/fnbeh.2010.00034

Brain recovery after alcohol and other drug use - Alcohol and Drug Foundation. (2022). Adf.org.au. https://adf.org.au/insights/brain-recovery-after-aod

DOI: 10.61366/2576-2176.1153

Brain Reward Response Linked to Binge Eating and ADHD. (n.d.). CHADD. https://chadd.org/adhd-news/adhd-news-adults/brain-reward-response-linked-to-binge-eating-and-adhd/

Brockett, A. T., Pribut, H. J., Vázquez, D., & Roesch, M. R. (2018). The impact of drugs of abuse on executive function: characterizing long-term changes in neural correlates following chronic drug exposure and withdrawal in rats. *Learning & Memory*, *25*(9), 461–473. http://www.learnmem.org/cgi/doi/10.1101/lm.047001.117

Cardinal, R. N., & Howes, N. J. (2005). Effects of Lesions of the Nucleus Accumbens Core on Choice between Small Certain Rewards and Large Uncertain Rewards in Rats. *BMC Neuroscience, 6*(1), 37. https://doi.org/10.1186/1471-2202-6-37

Coria-Avila, G. A., Herrera-Covarrubias, D., Ismail, N., & Pfaus, J. G. (2016). The role of orgasm in the development and shaping of partner preferences. *Socioaffective Neuroscience & Psychology*, *6*(1), 31815. https://doi.org/10.3402/snp.v6.31815

Costa, V. D., Tran, V. L., Turchi, J., & Averbeck, B. B. (2014). Dopamine modulates novelty seeking behavior during decision making. *Behavioral Neuroscience*, *128*(5), 556–566. https://psycnet.apa.org/doi/10.1037/a0037128

Davis, C., Cohen, A., Davids, M., & Rabindranath, A. (2015). Attention-Deficit/Hyperactivity Disorder in Relation to Addictive Behaviors: A Moderated-Mediation Analysis of Personality-Risk Factors and Sex. *Frontiers in Psychiatry*, *6*. https://doi.org/10.3389/fpsyt.2015.00047

Delgado, M. R., Jou, R. L., & Phelps, E. A. (2011). Neural Systems Underlying Aversive Conditioning in Humans with Primary and Secondary Reinforcers. *Frontiers in Neuroscience*, *5*. https://doi.org/10.3389/fnins.2011.00071

Eshel, N., Touponse, G. C., Wang, A. R., Osterman, A. K., Shank, A. N., Groome, A. M., Taniguchi, L., Cardozo, D. F., Tucciarone, J., Bentzley, B. S., & Malenka, R. C. (2023). Striatal dopamine integrates cost, benefit, and motivation. *Neuron*. https://doi.org/10.1016/j.neuron.2023.10.038

Fernandez, V. (2022, August 22). Social Media, Dopamine, and Stress: Converging Pathways. *Dartmouth Undergraduate Journal of Science*. https://sites.dartmouth.edu/dujs/2022/08/20/social-media-dopamine-and-stress-converging-pathways/

Fong, T. W. (2019). Understanding and managing compulsive sexual behaviors. *Psychiatry (Edgmont (Pa. : Township))*, *3*(11), 51–58. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2945841/

Gepshtein, S., Li, X., Snider, J., Plank, M., Lee, D., & Poizner, H. (2014). Dopamine Function and the Efficiency of Human Movement. *Journal of Cognitive Neuroscience*, *26*(3), 645–657. https://doi.org/10.1162/jocn_a_00503

Grace, A. A. (2016). Dysregulation of the dopamine system in the pathophysiology of schizophrenia and depression. *Nature Reviews Neuroscience*, *17*(8), 524–532. https://doi.org/10.1038/nrn.2016.57

Gruber, A. J., Hussain, R. J., & O'Donnell, P. (2009). The Nucleus Accumbens: A Switchboard for Goal-Directed Behaviors. *PLoS ONE*, *4*(4), e5062. https://doi.org/10.1371/journal.pone.0005062

Guo, G., Tong, Y., Xie, C.-W., & Lange, L. A. (2007). Dopamine transporter, gender, and number of sexual partners among young adults. *European Journal of Human Genetics*, *15*(3), 279–287. https://doi.org/10.1038/sj.ejhg.5201763

Hanlon, C. A., Dowdle, L. T., Austelle, C. W., DeVries, W. H., Mithoefer, O. J., Badran, B. W., & George, M. S. (2015). *What goes up, can come down: Novel brain stimulation paradigms may attenuate craving and craving-related neural circuitry in substance dependent individuals*. *1628*, 199–209. https://doi.org/10.1016/j.brainres.2015.02.053

Harline, D. (2015, December 23). *Why Are Some People More Vulnerable to Addiction than Others • Alpine Recovery Lodge*. Alpine Recovery Lodge. https://www.alpinerecoverylodge.com/why-are-some-people-more-vulnerable-to-addiction-than-others/

Hartston, H. (2012). The Case for Compulsive Shopping as an Addiction. *Journal of Psychoactive Drugs*, *44*(1), 64–67. https://doi.org/10.1080/02791072.2012.660110

Hedgcock, W. M., Vohs, K. D., & Rao, A. R. (2012). Reducing self-control depletion effects through enhanced sensitivity to implementation: Evidence from fMRI and behavioral studies. *Journal of Consumer Psychology*, *22*(4), 486–495. https://doi.org/10.1016/j.jcps.2012.05.008

Jansen, M., Overgaauw, S., & Ellen. (2024). L-DOPA and oxytocin influence the neural correlates of performance monitoring for self and others. *Psychopharmacology*. https://doi.org/10.1007/s00213-024-06541-9

Javed, K., Reddy, V., & Lui, F. (2021). Neuroanatomy, Cerebral Cortex. In *www.ncbi.nlm.nih.gov*. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK537247/?report=printable

DOI: 10.61366/2576-2176.1153

Kempadoo, K. A., Mosharov, E. V., Choi, S. J., Sulzer, D., & Kandel, E. R. (2016). Dopamine release from the locus coeruleus to the dorsal hippocampus promotes spatial learning and memory. *Proceedings of the National Academy of Sciences*, *113*(51), 14835–14840. https://doi.org/10.1073/pnas.1616515114

Klanker, M., Sandberg, T., Joosten, R., Willuhn, I., Feenstra, M., & Denys, D. (2015). Phasic dopamine release induced by positive feedback predicts individual differences in reversal learning. *Neurobiology of Learning and Memory*, *125*, 135–145. https://doi.org/10.1016/j.nlm.2015.08.011

Kral, T. R. A., Schuyler, B. S., Mumford, J. A., Rosenkranz, M. A., Lutz, A., and Davidson, R. J. (2018). Impact of short- and long-term mindfulness meditation training on amygdala reactivity to emotional stimuli. *Neuroimage 181*, 301–313. https://doi.org/10.1016/j.neuroimage.2018.07.013

Lamichhane, B., Di Rosa, E., & Braver, T. S. (2022). Delay of gratification dissociates cognitive control and valuation brain regions in healthy young adults. *Neuropsychologia*, *173*, 108303. https://doi.org/10.1016/j.neuropsychologia.2022.108303

Latzman, R. D., Taglialatela, J. P., & Hopkins, W. D. (2015). Delay of gratification is associated with white matter connectivity in the dorsal prefrontal cortex: a diffusion tensor imaging study in chimpanzees (Pan troglodytes). *Proceedings of the Royal Society B: Biological Sciences*, *282*(1809), 20150764. https://doi.org/10.1098/rspb.2015.0764

Li, C., Liu, S., Lu, X., & Tao, F. (2019). Role of Descending Dopaminergic Pathways in Pain Modulation. *Current Neuropharmacology*, *17*(12), 1176–1182. https://doi.org/10.2174/1570159x17666190430102531

Loonen, A. J. M., & Ivanova, S. A. (2017). Evolution of circuits regulating pleasure and happiness with the habenula in control. *CNS Spectrums*, *24*(02), 233–238. https://doi.org/10.1017/s1092852917000748

Luo, S. X., & Huang, E. J. (2016). Dopaminergic Neurons and Brain Reward Pathways. *The American Journal of Pathology*, *186*(3), 478–488. https://doi.org/10.1016/j.ajpath.2015.09.023

Melis, M. R., Sanna, F., & Argiolas, A. (2022). Dopamine, Erectile Function and Male Sexual Behavior from the Past to the Present: A Review. *Brain Sciences*, *12*(7), 826. https://doi.org/10.3390/brainsci12070826

Mercadante, A. A., & Tadi, P. (2022). *Neuroanatomy, Gray Matter*. PubMed; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK553239/

Meyer, P. J., King, C. P., & Ferrario, C. R. (2015). Motivational Processes Underlying Substance Abuse Disorder. *Behavioral Neuroscience of Motivation*, 473–506. https://doi.org/10.1007/7854_2015_391

Moccia, L., Mazza, M., Nicola, M. D., & Janiri, L. (2018). The Experience of Pleasure: A Perspective between Neuroscience and Psychoanalysis. *Frontiers in Human Neuroscience*, *12*(359). https://doi.org/10.3389/fnhum.2018.00359

Muraven, M., Tice, D. M., & Baumeister, R. F. (1998). Self-control as limited resource: regulatory depletion patterns. Journal of personality and social psychology, 74(3), 774–789. https://doi.org/10.1037//0022-3514.74.3.774

Myerson, J., & Green, L. (1995). Discounting of delayed rewards: models of individual choice. *Journal of the Experimental Analysis of Behavior*, *64*(3), 263–276. https://doi.org/10.1901/jeab.1995.64-263

Oscar Berman, M., Blum, K., Chen, T. J., Braverman, E., Waite, R., Downs, W., Arcuri, V., Notaro, A., Palomo, T., & Comings, D. (2008). Attention-deficit-hyperactivity Disorder and Reward Deficiency Syndrome. *Neuropsychiatric Disease and Treatment*, *4*(5), 893–918. https://doi.org/10.2147/ndt.s2627

Quaglia, J. T., Zeidan, F., Grossenbacher, P. G., Freeman, S. P., Braun, S. E., Martelli, A., Goodman, R. J., & Brown, K. W. (2019). Brief mindfulness training enhances cognitive control in socioemotional contexts: Behavioral and neural evidence. *PloS one*, *14*(7), e0219862. https://doi.org/10.1371/journal.pone.0219862

Schultz, W. (2016). Dopamine reward prediction error coding. *Dialogues in Clinical Neuroscience*, *18*(1), 23–32. https://doi.org/10.31887/dcns.2016.18.1/wschultz

Simpson, E. H., & Balsam, P. D. (2016). The Behavioral Neuroscience of Motivation: An Overview of Concepts, Measures, and Translational Applications. *Current Topics in Behavioral Neurosciences*, *27*(27), 1–12. https://doi.org/10.1007/7854_2015_402

Solié, C., Girard, B., Righetti, B., Tapparel, M., & Bellone, C. (2021). VTA dopamine neuron activity encodes social interaction and promotes reinforcement learning through social prediction error. *Nature Neuroscience*. https://doi.org/10.1038/s41593-021-00972-9

Szczypka, M. S., Kwok, K., Brot, M. D., Marck, B. T., Matsumoto, A. M., Donahue, B. A., & Palmiter, R. D. (2001). Dopamine Production in the Caudate Putamen Restores Feeding in Dopamine-Deficient Mice. *Neuron*, *30*(3), 819–828. https://doi.org/10.1016/s0896-6273(01)00319-1

Torrico, T. J., & Abdijadid, S. (2019, February 10). *Neuroanatomy, Limbic System*. Nih.gov; StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK538491/

Wahlstrom, D., Collins, P., White, T., & Luciana, M. (2010). Developmental Changes in Dopamine Neurotransmission in Adolescence: Behavioral Implications and Issues in Assessment. *Brain and Cognition*, *72*(1), 146. https://doi.org/10.1016/j.bandc.2009.10.013

Wise, R. A., & Robble, M. A. (2020). Dopamine and Addiction. *Annual Review of Psychology*, *71*(1), 79–106. https://doi.org/10.1146/annurev-psych-010418-103337

Yu, Y., Miller, R., & Groth, S. W. (2022). A literature review of dopamine in binge eating. *Journal of Eating Disorders*, *10*(1). https://doi.org/10.1186/s40337-022-00531-y

Yuan, P., Tragon, T., Xia, M., LeClair, C. A., Skoumbourdis, A. P., Zheng, W., Thomas, C. J., Huang, R., Austin, C. P., Chen, G., & Guitart, X. (2011). Phosphodiesterase 4 inhibitors enhance sexual pleasure-seeking activity in rodents. *Pharmacology Biochemistry and Behavior*, *98*(3), 349–355. https://doi.org/10.1016/j.pbb.2011.02.001

Zanna, M. P. (1992). *Advances in experimental social psychology. Volume 25* (pp. 345–402). Academic Press.

Zemishlany, Z. (2010). CS05-02 - The involvement of dopamine in human sexuality. *European Psychiatry*, *25*, 155. https://doi.org/10.1016/S0924-9338(10)70155-3