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# Pornography's Effect on the Brain: A Review of Modifications in the Prefrontal Cortex

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**Cover Page Footnote**
Thank you to Topher P. Taylor

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# A Review of Modifications in the Prefrontal Cortex

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Abstract

Pornography use has exponentially increased in the past 10 years. Most believe pornography use is largely a harmless behavior. Although sexuality is innate, hyper-sexual behavior, such as pornography use, has become increasingly commonplace. Addiction research has found that long-term substance addiction contributes to changes in brain volume (Hong et al., 2013; Zhou et al., 2011). Recent studies have shown that behavioral addictions also have similar volume loss as substance abuse (Hong et al., 2013). Research has shown that the particular area most affected is the prefrontal cortex (Hong et al., 2013). The prefrontal cortex, which oversees regulating self-control, decreases in size when exhibiting addictive behaviors (Hong et al., 2013). The cause of behavioral addictions like pornography addiction comes from prefrontal cortex areas such as the DLPFC, vlPFC, and vmPFC (Zhou et al., 2011). This effect on the prefrontal cortex has been shown to be particularly marked in participants with pornography addiction (Kühn & Gallinat, 2014). Pornography use has been shown to decrease the gray matter of the prefrontal cortex compared to baseline, thereby decreasing decision making. This affect to the cortices dedicated to decision making and self-control may contribute to why pornography use can be addictive.

Pornography's Effect on the Brain:

A Review of Modifications in the Prefrontal Cortex

Pornography is an ever-increasing influence as society has seen exponential expansion towards the accessibility of sexual content. A larger online community and continuing Internet growth have contributed to a significant increase in access to sexual images, causing sexual images and other forms of media to become ubiquitous (Hilton & Watts, 2011; Sirianni & Vishwanath, 2016). This increase of accessibility to sexual media has led to an increase of sex consumption, creating an environment where pornography is commonplace, and in some cases, addictive (Hilton & Watts, 2011; Sirianni & Vishwanath, 2016). Although sex/pornography addiction is not currently a diagnosis in the DSM-5, the following article will discuss the research thus far (Krueger, 2016). This literature review will primarily discuss the physical brain changes that happen when viewing pornography.

The brain is motivated to seek reward through multiple neurotransmitters, the most prominent being dopamine (DA), but when addiction takes hold, the brain is rewired to crave the particular behavior instead of natural rewards (Kim et al., 2017). Completely independent of the individual's cognitive self-control, the addiction routes the part of the brain that is likely to contain self-control, affecting the power to correctly choose the most beneficial behavior for the individual's life (Hald & Malamuth, 2008; Kühn & Gallinat, 2014). Though an addiction to pornography is rare considering the millions who have viewed sexual images (Ybarra & Mitchell, 2005), it can be classified as an addictive behavior in which participants have binging and withdrawal cycles and feel out of control in their behavior towards cybersex because they are abstaining for a time and then indulging excessively (Ko et al., 2009; Snagowski, Laier, Duka, & Brand, 2016). There are a wide variety of different aspects of internet sex addiction.

These include viewing online pornography, petitioning escorts, videoing webcam sex, and engaging in prostitution (Snagowski et al., 2016). Although all are considered forms of cybersex, the focus of this review will be the behavioral addiction of viewing online pornography.

Although the adverse psychological consequences of pornography addiction have been documented (Bothe, Toth-Kiraly, Demetrovics, & Orosz, 2017; Perry, & Davis, 2017; Perry, & Snawder, 2017), the physiological effects have been far less researched. Saturation of pornography in society has led many to ignore the negative effects of the addiction (Hald & Malamuth, 2008). Some believe pornography has no long term physiological effects on the participant, and today's culture facilitates this belief with the increase of mainstream sexual images in the news, media, and entertainment. The physiological effects of pornography include decrease of brain matter, which may lead to depression and low self-esteem (Brand, Snagowski, Laier, & Maderwald, 2016). Despite documentation of these effects, pornography use continues to increase (Owens et al., 2012).

Behavioral addictions, such as pornography addiction, have been studied less than substance addictions (Kühn & Gallinat, 2014; Laier & Brand, 2014). These types of addictions have no ingested physical substance affecting the body's natural functions. Nonetheless, recent research shows that behavioral addictions such as viewing pornography and gambling are more similar to substance addictions than previously thought (Kühn & Gallinat, 2014; Love, Laier, Brand, Hatch, & Hajela, 2015). Scientists have researched the physical side effects of pornography consumption and have helped researchers to gain insight into the long term changes the brain undergoes when looking at pornography (Laier & Brand, 2014; Love et al., 2015). Pornography's similarities to substance addictions are vital to understand to begin to apply substance addiction methods to pornography addiction.

Several studies have shown that behavioral addiction is comparable to substance addictions such as cocaine, methamphetamine, and tobacco use (Goudriaan, De Ruiter, Van Den Brink, Oosterlaan, & Veltman, 2010; Ko et al., 2009). Behavioral addiction has similarities to substance addiction in several ways: (1) pleasure chemicals in the brain are released in excessive amounts in comparison to natural stimuli. This is akin to the consumption of physical substance. As more of the substance is consumed, the brain begins to rely on these abnormal amounts of neuron firing to receive the same sensation (Bostwick & Bucc, 2008; Hilton & Watts, 2011); (2) several parts of the brain have been shown to have significant tissue decrease in the PFC compared with the individual’s baseline as seen in with those seen in substance abuse (Feil et al., 2010; Zhou et al., 2011); (3) the brain has been rewired to seek reward from the harmful behavioral substance just as it would from a physical substance (Garavan et al., 2000); and (4) the individdoes not usually comprehend the magnitude of the effect on his or her lifestyle and behavior when addicted (Hald & Malamuth, 2008).

In evaluating the studies surrounding affected areas of the brain, researchers have found the prefrontal cortex is most affected (Dong, Lin, & Potenza, 2015; Hald & Malamuth 2008; Volkow et. al., 2005). The prefrontal cortex (PFC) contributes to several vital functions for an individual. The PFC gray matter correlates with higher operating functions, such as planning complex behaviors, exhibiting self-control, and moderating decision making, which are all altered in both substance and behavioral addictions (Dong et al., 2015; Hald & Malamuth 2008; Volkow et. al., 2005). Addiction research on the PFC has associated this gray matter with the self-control and preference attribution of an individual (Volkow et. al., 2005). This research has been highly beneficial in understanding why participants become and stay addicted. Accordingly, the PFC can be affected when watching pornography; the behavior becomes addicting as the part of the brain operating the person's self-control slowly deteriorates from the individual's baseline (Sutterer, Koscik, & Tranel, 2015).

Deterioration of the PFC can cause a vicious cycle: the more pornography is viewed, the more the PFC gray matter deteriorates, leading the self-control to decay (Kim et al., 2017; Kühn & Gallinat, 2014). This loss of self-control could be why pornography seems to be an addictive behavior. Studies have shown that pornography may be as hard to overcome as any other substance or behavioral addiction (Goudriaan et al., 2010; Kühn & Gallant, 2014). Some research has also been done concerning the brain matter changes that occur predating the addiction, but the article will focus primarily on an individual's baseline and occurrence of gray matter after addiction (Ersche et al., 2012; Kühn & Gallinat, 2014). The decay of the gray matter is critical when considering brain changes from viewing pornography. Although some consider frequent pornography use a harmless form of entertainment, pornography addiction can result in physical changes, specifically the shrinking of gray matter, causing a loss of healthy neurons, which diminishes the executive function critical to effective decision-making and self-control. This paper will discuss in detail the similarities between substance and behavioral addictions such as pornography, including the parallels of the addiction cycle, the changes made to the PFC, and the loss of self-control as a result of this brain matter decrease.

## The Cycle of Addiction and its Effect on Substance and Behavioral Addictions

DA is the neurohormone chemical for addiction, meaning DA increases the rate of neuron firing when a pleasurable stimulus is offered. DA is known as the pleasure neurotransmitter, helping the body receive satisfaction for rewarding activities (Groman & Jentsch, 2012). Natural releases of DA in the brain include the stimuli of exercise, consumption of food, and sexual behavior (Groman & Jentsch, 2012; Kim et al., 2017). The chemical DA starts the cycle of addiction by flooding the brain with the feeling of pleasure in response to the addictive behavior. Pornography is a heavily exaggerated version of natural sexual activity and, as such, the brain both outpours more DA than a normal stimulant and creates changes in the neural receptors (Brand et al., 2016; Dong et al., 2015).

The cycle of addiction begins with the PFC craving the desired substance or behavior. Although the brain receives DA from certain natural functions such as food, water, and sex, the manifestation of an addict starts with DA flooding the limbic system with an unnaturally high amount, not allowing the addict to think about much else other than the substance or behavior (Fattore, Melis, Fadda, Pistis, & Fratta, 2010; Georgiadis & Kringelbach, 2012). This creates a strong motivation for the stimuli and the addict learns to binge on said substance or behavior. When an addict engages in viewing pornography, this may mean that they are in the intoxication phase of the addiction cycle, impairing the addict's brain from choosing other options (Berridge & Robinson, 2016; Goldstein & Volkow, 2011; see Figure 1).

Loss of self-control has been shown to come from the PFC becoming deactivated when watching pornography (Kim et al., 2017; Kühn & Gallinat, 2014). When the binging of the behavior is done, the limbic, or most primitive part of the brain, is satisfied and the PFC is stimulated (Berridge & Robinson, 2016; Hald & Malamuth, 2008). Once stimulated, the part of the PFC associated with self-control and higher-level thinking regrets the compulsive action (Berridge & Robinson, 2016; Hald & Malamuth, 2008). After an individual has gone through this cycle, the PFC will associate this period of withdrawal with increased psychological and physiological stress because of the lower levels of DA (Brand et al., 2016; Dong et al., 2015). This stress can contribute to many side effects, such as depression, grief, feelings of inadequacy, and low self-esteem, leading the participant's brain to desire escaping these feelings and participate in the substance or behavior again (Berridge & Robinson, 2016; Hald & Malamuth, 2008). The cycle of craving, intoxication, binging, and withdrawal indicate reduced self-control (Kühn & Gallinat, 2014; Owens, et al., 2012). Pornography users may be disadvantaged when trying to quit when they have lost many synapses in the cortical area of the PFC associated with self-control.

Notably, behavioral addictions such as pornography and gambling addictions have few physical substances ingested to hold responsible when determining why the body craves the behavior. Although some uncommon situations can result in pornography addiction such as individuals who ingest dopaminergic agonists can be more prone to addictive behaviors, a behavioral addiction in an otherwise healthy adult usually has no physical ingestion to cause the addiction (Imamura, Uitti, & Wszolek, 2007). Behavioral addiction is similar to substance addiction but defined as any behavior, not involving ingestion of a drug, in which an individual compulsively seeks out the stimuli or feeling brought about. (Alavi et al., 2012; Owens et al., 2012; Peter, & Valkenburg, 2016). Individuals who are addicted to pornography physically crave the behavior, as shown in their cortical changes and their DA levels, and experience negative consequences from the frequency of the activity overriding other important aspects in their lives (Owens et al., 2012; Price, Patterson, Regnerus. & Walley, 2016).

For substance addictions, such as nicotine, cocaine, and methamphetamine addiction, literature has shown the potential for the substance to alter gray matter in the brain modules associated with self-control (Goldstein & Volkow, 2011; Goudriaan et al., 2010; Zubieta el al., 2005). Physical substances increase blood flow to the PFC, leading the brain to crave more of the substance (Feil et al., 2010; Voon et al., 2014; Zubieta et al., 2005). The surge of regional cerebral blood flow (rCBF) and decrease in gray matter occurs right after the consumption or binging of pornography as well. This continues each time the individual engages in pornography, as he PFC becomes accustomed to the abnormal amounts of rCBF (Goldstein & Volkow, 2011; Zubieta el al., 2005). Thus, when the PFC grows accustomed to this abnormal amount of rCBF it needs the inordinate amount of rCBF, associated with watching pornography, to satisfy the craving. The individual viewing pornography will rely on this behavior to receive the most blood flow, the individual can no longer receive the same heightened blood flow in natural activities, such as sexual intercourse (Park et al., 2016; Voon et al, 2014).

Habituation familiarizes the PFC to the drug, demanding more of the addictive behavior in order to achieve the same vast amount of rCBF and the increase of chemicals such as DA, the chemical compound thought to be responsible for the propitiation of pleasure (Groman & Jentsch, 2012; Kim et al., 2017). Pleasure is naturally wired to reward biologically necessary functions such as food consumption and sexual activities, but when addictive behaviors increase the DA more than the PFC is accustomed to, the PFC may continue to demand unnaturally elevated DA levels in the brain in order to achieve the same stimulation (Cabanac, Guillaume, Balasko, & Fleury, 2002; Kim et al., 2017). Thus, the individual may continue to seek the behavior to maintain the DA levels associated with the elevated pleasure.

It is important to realize behavioral addictions have long been perceived in popular press as a problem of low willpower instead of a brain-altering addiction (Laier & Brand, 2014; Love et al., 2015). This notion contributes little to the neuroscience of addiction (Hong et al., 2013; Volkow & Morales, 2015). Most individuals with a behavioral addiction do not want to be addicted. Addiction seems to inconvenience the participant at best, and at worst, can be responsible for pornography becoming more important than the physical, mental, social, or emotional needs of the individual, causing distress (Hong et al., 2013; Volkow & Morales, 2015). Individuals with behavioral addictions act on the addictive behavior above all other behaviors. The new priority of the behavior shows how the reward system of the brain likely becomes conditioned, thus increasing frequency of the behavior (Hong et al., 2013; Volkow & Morales, 2015). As a result, when the individual wants to engage in other activities, the reward system creates only a natural amount of DA in the natural pleasurable activity and does not create the same immense amount of stimulation as engaging in pornography. The DA is only released in the vast amount when the addictive behavior such as pornography is experienced, leading an individual to seek the large stimulation by viewing pornographic behavior (Hong et al., 2013; Volkow & Morales, 2015).

## Behavioral Addiction and Its Effect on the Brain

Neuroscience research shows that the brain functions as a whole but also confirms different parts of the brain's cortices and subcortical areas operate different functions in the human body (Bartels & Zeki, 2004)—one of the most influential being the discovery of Broca's aphasia (Bartels & Zeki, 2004). This type of aphasia, or damage in the brain, is caused when the part of the brain responsible for speech production is lesioned, causing an individual to have full mental capabilities of speech, but speech becomes labored (Fridriksson, Fillmore, Guo, & Rorden, 2015). Thus, certain modules of the brain focus on specific tasks. The specific functioning of brain areas has assisted research surrounding behavioral addictions like pornography. Pornography addiction could affect parts of the brain exclusively responsible for decision making.

To enumerate, specific tasks dedicated to each area of the brain have been studied extensively in the brain of addicts. Behavioral addiction alters the brain functions in several areas. First, addiction tends to decrease gray matter in the PFC, gray matter primarily in charge of the self-control and awareness of behavior (Goldstein & Volkow, 2011; Dong et al., 2015). This explains why the addict's particular behavior is prioritized over all other activities in his or her life (Hong et al., 2013; Volkow & Morales, 2015). Prioritizing an addictive behavior can create harmful situations to the addict. Instead of participating in the most beneficial choice for oneself, the individual will continue to turn to his or her addiction (Groman, & Jentsch, 2012; Hong et al., 2013; Kim, et al., 2017). In a healthy, un-addicted brain, the individual will choose the most comfortable and pleasurable choice for their lives (Cabanac et al., 2002). Behavioral addiction twists this natural function into desiring the behavior instead of desiring vital behaviors (Garavan et al., 2000).

Above all addiction affects the PFC by creating the release of chemical neurohormones, produced by nerve cells and then released into the rCBF (Groman, & Jentsch, 2012; Kim, et al., 2017). The brain releases DA when an individual accomplishes instinctively pleasurable actions (Groman, & Jentsch, 2012; Kim, et al., 2017). When stimuli that can cause this release of DA are intensified, the brain directs larger quantities of DA towards the addictive behavior (Kim, et al., 2017; Kühn & Gallinat, 2014). Over time, the more one consumes amplified, intensified views of sexual activity, the less the brain disperses DA to natural sexual responses found in phenomena of the physical world (Berridge & Robinson, 2016; Kühn & Gallinat, 2014).

**Regions Affected by Pornography Addiction**

The PFC has many different regions that may play a role in pornography addiction. Self-control has been shown to stem from the dorsolateral PFC (DLPFC) and the ventrolateral PFC (vlPFC) (Goldstein & Volkow, 2011; Dong et al., 2015).  Once the behavioral addiction of pornography has stimulated both the DLPFC and the vlPFC repeatedly, they are more activated by viewing pornography than physical sexual intercourse (Berridge & Robinson, 2016; Kühn &

Gallinat, 2014). Once the binge is over, the gray matter in the DLPFC and the vlPFC decrease due to overstimulation wearing on brain structure and deregulation of the PFC (Berridge & Robinson, 2016; Kühn & Gallinat, 2014). This deregulation may affect decision-making and self-discipline, provoking individuals viewing pornography to stay in a cycle of binging and craving because of the decreased gray matter in the PFC (Fecteau, Fregni, Boggio, Camprodon, & Pascual-Leone, 2010; Goldstein & Volkow, 2011).

At the onset the DLPFC becomes much more activated when an individual views a picture of sexual behavior, as shown in Figure 2 (Brand et al., 2016; Dong et al., 2015; Fecteau et al., 2010). Individuals who do not have an addiction to the behavior have no such activation in the DLPFC; addicts show significant increases. The DLPFC is likely to control the decisions made on a day-to-day basis (Brand et al., 2016; Dong et al., 2015; Fecteau et al., 2010). Thus, when the addiction has significantly rerouted the decision-making DLPFC, participants with addiction have been shown to have substantial increases of attention only when looking at pornography (Dong et al., 2015; Fecteau et al., 2010). The behavior does not have to enter the body or reach the bloodstream to chemically alter the brain. Accordingly, the behavioral addiction of pornography may be addicting in the same way as a substance addiction. The substance may not enter physically into the body, but, according to studies on the brain, it has similar effects on the PFC to ingesting the drug (Brand et al., 2016; Dong et al., 2015; Fecteau et al., 2010). For example, cocaine addicts can achieve the same arousal in the brain by viewing pictures of cocaine (Fecteau et al., 2010). This calls for researchers to look deeper into behavioral addiction originating from decreases in gray matter instead of attributing behavioral addictions to a lack of willpower.

When the PFC part of the brain is not fully activated or aware during the phase of intoxication, the body is no longer able to continue to choose the regulation of beneficial behaviors and pursuit of goals (Goldstein & Volkow, 2011). Intoxication increases likelihood that the participant of the pornography addiction will return to viewing pornography, even if he or she does not have a desire to (Berridge & Robinson, 2016). Their self-control and discipline are more and more inhibited each time they view pornography, leading them to have less control in stopping the pornography addiction (Goldstein & Volkow, 2011).

**Gray Matter Decreases in Pornography Addicts**

The ventromedial PFC (vmPFC) has been studied extensively in literature and is thought to be related to decision making (Brand, et al., 2016). The vmPFC could contribute to the addiction cycle by becoming dependent on pornography use. When an individual views pornography, decreases in the gray matter of the vmPFC leads to lower self-control (Kim et al., 2017; Kühn & Gallinat, 2014). This, in turn, conditions the vmPFC to respond with high alertness to the viewing of pornography, as seen in Table 1. When the behavioral addiction of pornography use affects the vmPFC, it may lead to impaired thinking, starting the intoxication stage of addiction, where the brain is stimulated by the thought of watching pornography, and the absence of pornography increases this thought until the participant can recognize the viewing of pornography as the logical response to the stimulus (Brand et al., 2016; Yamamoto, Woo, Wager, Regner, & Tanabe, 2015). This conditioning of the vmPFC triggers an undesirable emotion when the participant experiences a stressful situation of which the conditioned response would be to view pornography to ease stress (Yamamoto et al., 2015). The vmPFC has been shown to become narrowly focused on the behavior, allowing the individual to gain DA only from that amplified natural DA-initiating behavior, interfering with the more subdued environment humans have lived in for millions of years (Cabanac et al., 2002). In our ancestral heritage, human beings had no access to amplified sexual content, and only gained access through committing the act of copulation with another human, one of many ways to release DA. Under these circumstances of the vmPFC, the PFC has now become trained to seek out the reward of pornography, as it is now wired to deliver DA to reward centers in the PFC (Hyman, Malenka, & Nestler, 2006).

Having received the vast amount of DA the addictive behavior fabricates, the PFC is subdued, but only for a short time until the vmPFC craves the behavior again (Berridge & Robinson, 2016; Fattore et al., 2010). The participant may be able to recognize the impaired impulsivity of their actions at this point, until the decreased brain tissue signals for more stimulation (Hald & Malamuth, 2008). The medial PFC (mPFC) has also been shown to activate with the vmPFC in other addictions, such as cocaine addiction, to trigger activation when the drug is used, creating the craving effect seen in pornography addiction (Sutterer, Koscik, & Tranel, 2015; Volkow et al., 2005). Increased activation of the mPFC demonstrates that when the mPFC becomes addicted, it has a much higher response to the behavior, showing a link between the craving and the addictive behavior the individual prioritized.

The vlPFC is likely the area of the brain most responsible for regulating adverse risks and stopping high-risk behavior (Hyman et al., 2006; Seok, Lee, Sohn, & Sohn, 2015). The vlPFC exhibits decreased tissue volume and function when participants engage in viewing pornography and does not regulate the risky behavior as it should (Feil et al., 2010; Goldstein & Volkow, 2011; Kühn & Gallinat, 2014). When the regional brain of the vlPFC is deactivated, participants engage in more activities that could be harmful (Seok et al., 2015). In pornography usage over time, the brain decreases its physical size in the vlPFC, reducing alertness when engaging in risky activities (Feil et al., 2010; Goldstein & Volkow, 2011; Kühn & Gallinat, 2014). Discovery of the decrease of vlPFC gray matter has been statistically significant in lessening awareness of the risk involved with pornography (Goldstein & Volkow, 2011; Kühn & Gallinat, 2014). An individual may believe that he or she has control over the addiction and that the adverse side effects are small (Hald & Malamuth, 2008; Yamamoto et al., 2015). The decrease of matter pornography makes on the vlPFC hinders the executive functions of the brain to realize the adverse consequences acquired and puts the individual into an intoxicated phase (Kühn & Gallinat, 2014).

## Conclusion

Pornography use affects the executive functions of the brain, rewiring its structure, and decreasing gray matter volume (Kim et al., 2017; Kühn & Gallinat, 2014). Societal responses have been less than satisfactory concerning the view of behavioral addictions such as pornography, but research has now shown large correlations between the effects of substance abuse and behavioral addictions (Brand et al., 2016; Dong et al., 2015; Fecteau et al., 2010). Both substance and behavioral actions create the same reactions in the brain, increasing DA in the brain when the addictive substance is encountered, decreasing tissue in the vlPFC, mPFC, and DLPFC, and deactivating tissue likely responsible for the self-control and awareness of the participant (Fecteau et al., 2010; Goldstein & Volkow, 2011).

Regions of the PFC, including the vlPFC, mPFC, and the DLPFC, may have been shown to physically decrease in size with pornography addiction (Fecteau et al., 2010; Goldstein & Volkow, 2011). The decrease in gray matter is shown to have no long-term effect when a pornography individual breaks the cycle of addiction, and the gray matter of all brain areas increases back to an individual's baseline gray matter size (Kim et al., 2017; Kühn & Gallinat, 2014). This knowledge lends hope to individuals with pornography addictions, as the gray matter plasticity can recover and revive its functions strongly. An individual with pornography addiction can have their PFC gray matter increase, albeit slowly, and recover fully.

The increase of pornography interferes with the brain by altering years of biological and evolutionary characteristics that have kept humans alive (Fattore et al., 2010; Zhou et al., 2011). The actions of DA in the PFC during sexual activities have helped individuals to procreate, but the overstimulation of this process may result in a pornography addiction epidemic seen in today's modern society. Thus, what is a natural biological response to stimuli has created an interesting occurrence in the 21$^{st}$ century as individuals are oversupplied with the biological stimuli.

As scientists continue to explore the consequences that behavioral addictions have on the brain, research into pornography and other addictions will be critical to understanding how one handles the addictions and how doctors can best treat the individual that is in the grasp of a behavioral cycle that self-discipline alone cannot help. As the similarities between behavioral and substance addictions in the brain are mostly indistinguishable, behavioral addictions may be further treated with substance addiction recovery procedures such as group therapy, medications, and rehabilitation. More research into how pornography affects the vlPFC, DLPFC, and mPFC will help to achieve breakthroughs in how the brain functions when self-control is inhibited and how individuals with behavioral addictions, such a pornography use, become addicted and stay addicted. The more scientists research pornography addiction effects on the brain, the more success the medical world may achieve in helping individuals affected by the societal stigmas associated with behavioral addictions.

*Table 1. Perceived effects of the roles addiction plays in different parts of the PFC*

| PFC Region | Natural operation of region | Addiction's effect on region |
|---|---|---|
| DLPFC | Self-discipline, self-control, compulsivity | Compulsive behavior |
| vlPFC | Detection of monitoring behavior | Impaired self-monitoring |
| vmPFC | Motivation towards inclination for beneficial behavior | Motivation directed towards addictive substance or behavior |
| MPFC | Awareness about ones physical and emotional state | Denial, attention completely on substance or behavior |

*Note:* The prefrontal cortex (PFC) has several different parts believed to function in certain ways; the dorsolateral PFC (DLPFC), the ventrolateral PFC (vlPFC), the ventromedial PFC (vmPFC), and the medial PFC (mPFC). Adapted from Table 1: Processes associated with the prefrontal cortex that are disrupted in addiction (Goldstein & Volkow, 2011).

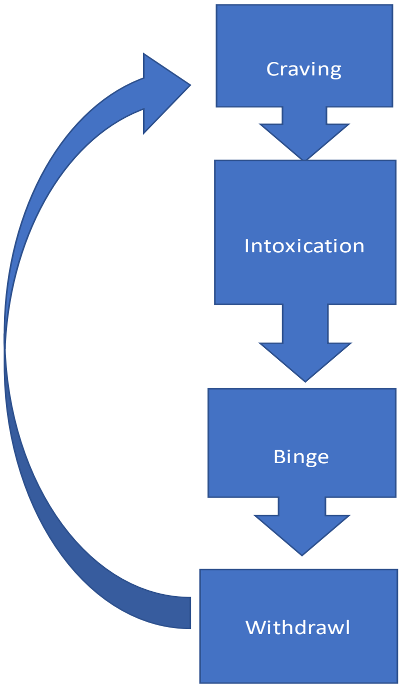


Figure 1. The basic four stage cycle of addiction in both substance and behavioral addictions. Adapted from several different journals including Brand et al., 2016; Dong et al., 2015; and Fecteau et al., 2010.

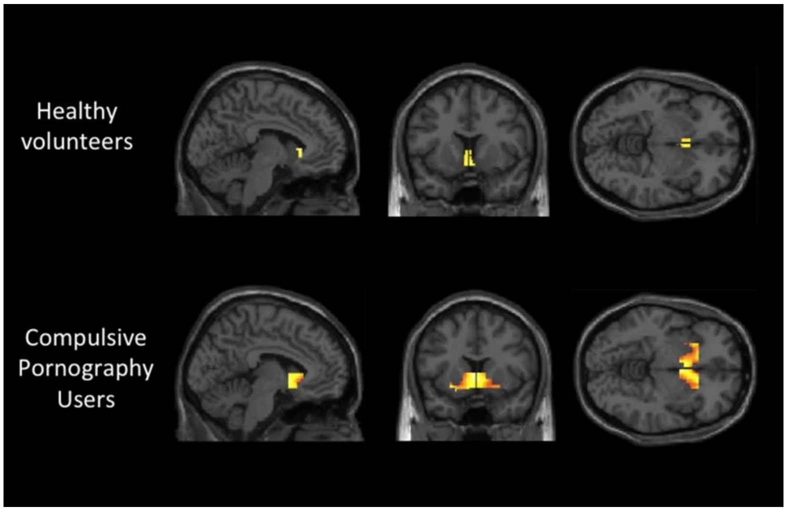


*Figure 2. Gray matter in the prefrontal cortex is hyperstimulated in pornography users, leading to a loss of healthy neurons similar to substance addictions. Reprinted from* “Neural correlates of sexual cue reactivity in individuals with and without compulsive sexual Behaviours,” *Plos ONE*, Voon et al., 2014.

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