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One last time: A systematic review comparing gambling and opioid addiction in the brain

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Abstract

Gambling disorder is today a common disorder causing lives to shatter. As this disorder activates the reward system and increases the need of dopamine, recovering from gamling disorder can be hard. Research has shown that gambling addiction appears to have similarities to substance abuse, but no substance has been named. Therefore, this systematic review discusses similarities and differences between gambling and opioid addiction. The aim is to compare behavior and neurological correlates of gambling and opioid addiction to create a better understanding of the relationship between these addictions and hopefully help improve treatments. My expectation was that I would find behavioral and neurological similarities between opioid and gambling addicts. To investigate this, I conducted a systematic search across databases. I compared six studies which all used a task to investigate decision-making ability and brain-scanning to investigate neural correlates. Both gambling and opioid addicts show decreased activation in the orbitofrontal cortex, which plays a central role in decision-making. Regarding task performance, some studies showed addicts to perform worse than controls, suggesting that addicts show an impaired decision-making ability compared to controls. This systematic review contributes to the literature within addiction, but to draw a conclusion that gambling and opioid addicts suffer from similar decision-making impairment further research is needed.

Keywords: opioids, gambling, decision-making, neural correlates

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Gambling is ubiquitous. All over, there are advertisements for gambling: on TV, radio, podcasts and in social media. It can seem like a fun, harmless, even exciting hobby if one knows when to stop. The ads show people winning, enticing them with a carefree life of no responsibilities; but most people who win do not end up with this incredible life. Rather, their lives often become complicated. Gambling depends on luck. For some, what began as a fun past-time leads to addiction. Gambling disorder is a disorder destroying not only the addict but family, relatives and everyone around. Struggling with lies and impulsivity, gambling addicts dream of the big jackpot, not realizing what is happening to them until too late.

Concerning gambling addiction, several studies have indicated that there are similarities between gambling and substance addiction (Dixon et al., 2014; Tanabe et al., 2007). That said, several authors do not mention which kind of substance they refer to. This thesis compares gambling and opioid addiction to see what their neurological and behavioral similarities are.

Gambling addiction

Gambling has ancient roots. Dice have been found in caves dating to 3500 BCE (Grant et al., 2015). Even though gambling has been a problem for so many years, it was not classified within the Diagnostic and Statistical Manual of Mental Disorders (DSM) as a psychiatric disorder until 1980 (American Psychiatric Association, 1980).

Gambling is classified as a disorder as soon as it develops into a problem, which is as soon as one cannot resist the impulse to play or continue playing. Often, the problem begins with hitting the jackpot and feeling a consequent high. The high encourages the person to take more risks: perhaps going for double or nothing, even if one knows that the house always win in the end, which means that one probably — almost certainly — will lose the jackpot. Having lost, one desperately tries to win it back, losing more and more money and getting stuck in the gambling wheel in the process (see, e.g., Morrison, 2014). One common mistake that gamblers often fall for is the so-called *gambler's fallacy*. This is the idea that the occurrence of previous events, like coin tosses, affects the probability of future events that are actually independent of the earlier ones (see, e.g., Clotfelter & Cook, 1993).

In the DSM-5 (American Psychiatric Association, 2013), the diagnosis of pathological gambling was renamed to "gambling disorder" and moved from impulse control disorders to substance-related and addictive disorders. At the same time, the diagnostic criteria for being classified as a gambling addict were lowered from five to four out of nine criteria, to make it easier to diagnose individuals with the disorder. These changes were based on empirical research showing that substance use disorder and gambling disorder have much in common (Weinstock & Rash, 2014).

The criteria for being diagnosed as a gambling addict are that the patient "(1) needs to gamble with increasing amounts of money in order to achieve the desired excitement; (2) is restless or irritable when attempting to cut down or stop gambling; (3) has made repeated unsuccessful efforts to control, cut back, or stop gambling; (4) is often preoccupied with gambling (e.g., having persistent thoughts of reliving past gambling experiences, handicapping or planning the next venture, thinking of ways to get money with which to gamble); (5) often gambles when feeling distressed (e.g., helpless, guilty, anxious, depressed); (6) after losing money gambling, often returns another day to get even (chasing one's losses); (7) lies to conceal the extent of involvement with gambling; (8) has jeopardized or lost a significant relationship, job, or educational or career opportunity because of gambling; and (9) relies on others to provide money to relieve desperate financial situations caused by gambling" (American Psychiatry Association, 2013, Section 312.31).

Opioid addiction

Opioids are a category of drugs that can be prescribed by your doctor, primarily used to treat pain or induce sleep; but they can just as easily be obtained illegally on the street (e.g., heroin, a natural opiate, or fentanyl, an artificial one). The substance morphine occurs naturally in the opium poppy plant and targets opioid receptors in the brain to produce a calm feeling, resulting in a euphoric rush. As opioid abuse progresses, one develops a tolerance for the drug, needing to use more to get the same effect. If one cannot get hold of the drug and usage is interrupted, one experiences such severe withdrawal symptoms as extreme nausea, diarrhea, runny nose and goosebumps. These symptoms are so extreme that they motivate one to continue drug use, no matter the long-term consequences (Moningka et al., 2019).

Koob and LeMoal (1997, as cited in Koob, 2010) divide addiction into three stages: binge use/ intoxication, negative emotionality, and craving during withdrawal. The first stage, intoxication, is when one takes the drug. This activates neurotransmitters in the midbrain (controlling wakefulness), striatum (including the caudate nucleus, putamen and nucleus accumbens, controlling decision-making and reward related behavior) and prefrontal cortex (controlling executive function), creating a positive association between the euphoria and the drug. The second and third phase occur when one does not have access to the drug, which causes one to experience negative emotions and withdrawal craving. That activates the stress systems. As these feelings increase, one is motivated to obtain more drugs (Everitt & Robbins, 2005).

Similarities between opioid and gambling addiction

According to various studies, gambling (see, e.g., Linnet et al., 2011) and opioids (see, e.g., Spagnolo et al., 2019) alike activate the so-called *reward centers* of the brain, including the ventral striatum. The ventral striatum supplies one with motivation and pleasure by releasing a large amount of dopamine together with opioid peptides (which bind with opioid receptors and control voluntary movement, reward response and motivational behavior; Juárez Olguín et al., 2016), serotonin (which among other things functions as a mood stabilizer; Berger et al., 2009), γ-aminobutyric acid/GABA (an inhibitory neurotransmitter that deactivates parts of the nervous system; Hepsomali et al., 2020) and acetylcholine (an excitatory neurotransmitter that changes neuronal networks; Picciotto et al., 2012). Through the ventral striatum goes the mesolimbic dopamine pathway, connecting the ventral tegmental area (which controls reward-related behavior, motivation, motor function and addiction; Trutti et al., 2019) with the nucleus accumbens (which controls motivational behavior; De Groote & d'Exaerde, 2021) located in the ventral striatum. Feeling of reward — together with withdrawal symptoms — drive addicts to continue their addiction despite the consequences (Koob & Volkow, 2016).

Both gambling (see, e.g., Reuter et al., 2005) and opioid (see e.g., Gorzelanczyk et al., 2014) addicts have problems with executive control circuits located in the prefrontal cortex, making it hard to make decisions and control impulses. The Iowa gambling task (introduced by Bechara et al., 1994) can be used to examine this relationship. One is asked to choose between a short-term reward with fewer advantages in the long term vs. a long-term reward with fewer advantages in the short-term. This task generally activates the ventral striatum, amygdala (controls emotions, behavior, and memory; AbuHasan et al., 2021) and insula (sensory processing e.g., decision-making, empathy; Uddin et al., 2017). Both gambling and opioid addicts mostly choose the short-term reward. This shows that levels of risk taking are higher in individuals suffering from addiction (Gorzelańczyk et al., 2021). In general, addicts tend to choose short-term reward regardless of long-term consequences, such as stealing money instead of waiting for a paycheck. This helps explain the addict's problems regarding jobs, family, and relations.

Yan et al. (2014) compared participants affective decision-making ability using a standard presentation of the Iowa gambling task; participants were asked to select one of four cards (A, B, C, D) 100 times, unknowing of the outcome. Cards A and B yielded high immediate gain but risked a bigger loss, while cards C and D yielded smaller gain but also smaller loss. Participants were 58 heroin addicts (age 23-48), 58 gambling addicts (age 20-50), and 60 controls matched in age. Both heroin and gambling addicts performed worse on the Iowa gambling task compared to controls, as measured by more often choosing card A or

B than card C or D. The authors conclude that gambling and opioid addicts have similarly impaired decision-making compared to controls.

Physical versus psychological addiction

One difference between opioid and gambling addiction is the way the addiction manifests. Gambling addiction is predominantly psychological, opioid addiction predominantly physiological. For an addiction to be considered physiological, one must experience withdrawal symptoms if one stops using the substance, making the body ill. Gambling withdrawal, on the other hand, lacks such symptoms. Gambling addiction activates neurotransmitters that increase levels of dopamine and serotonin, which in turn increase the urge to gamble. When one tries to stop gambling, the body does not become ill, but one experiences such symptoms as anxiety, stress, and anger (Alavi et al., 2012).

Neuroimaging methods

This review includes articles using both functional and structural brain scanning methods. Functional brain scanning methods such as functional magnetic resonance imaging (fMRI) show activity changes through blood flow and oxygenation. They are used to detect strength of activation during a task or while in resting state. Positron emission tomography (PET) works similarly to fMRI but requires a radioactive substance to be injected into the body to follow activation patterns in the brain. Structural brain-scanning methods such as magnetic resonance imaging (MRI) show the brain's structure to get a visual idea of the brain. They are used to detect brain damage or to analyze volume within substructures (Hirsch et al., 2015). These are among the most widely used brain-scanning methods. They enable me to compare neurological activation and structure within gambling and opioid addicts instead of just looking at behavioral differences as some studies (see e.g., Yan et al., 2014) have done.

Aim of this study

Concerning earlier mentioned similarities, gambling and opioid addiction seem quite similar. The aim of this systematic review is to examine the behavioral and neurological similarities between gambling and opioid addiction focusing on decision making. To this end, I present brain-scanning studies on gambling and opioid addicts, as well as considering studies from the psychology literature where relevant. The research question posed by this thesis is, do gambling and opioid addiction produce similar behavior and neurological patterns in the brain while making decisions? If they do, is it possible that these addictions reflect a common underlying condition which should be treated similarly? By comparing them, knowledge about these addictions will hopefully increase, which can help in developing treatments. My hypothesis is that I *will* find behavioral and neurological similarities between gambling and opioid addicts.

Methods

Search strategy

I performed the search 6 April 2022 on the databases Web of Science and Scopus. My search string is (neuroimaging OR fMRI OR "brain scanning" OR PET OR MRI) AND (gambling OR opioid) AND addiction AND "decision-making", resulting in *n*=165 results in Web of Science and *n*=126 in Scopus. One article was included from the reference list of an included article in the systematic review (Lee et al., 2005) because of its relevant content, total *n*=292. I removed 68 duplicates by hand, working in Endnote, which was my bibliographical management software, resulting in records screened *n*=224. Removing 196 articles that were not experimental studies (as determined by title and abstract), left me with *n*=28. Twenty-two articles were excluded based on inclusion/exclusion criteria applied to the full text. The included studies were *n*=6, with three addressing decision-making in opioid addiction and three decision-making in gambling addiction

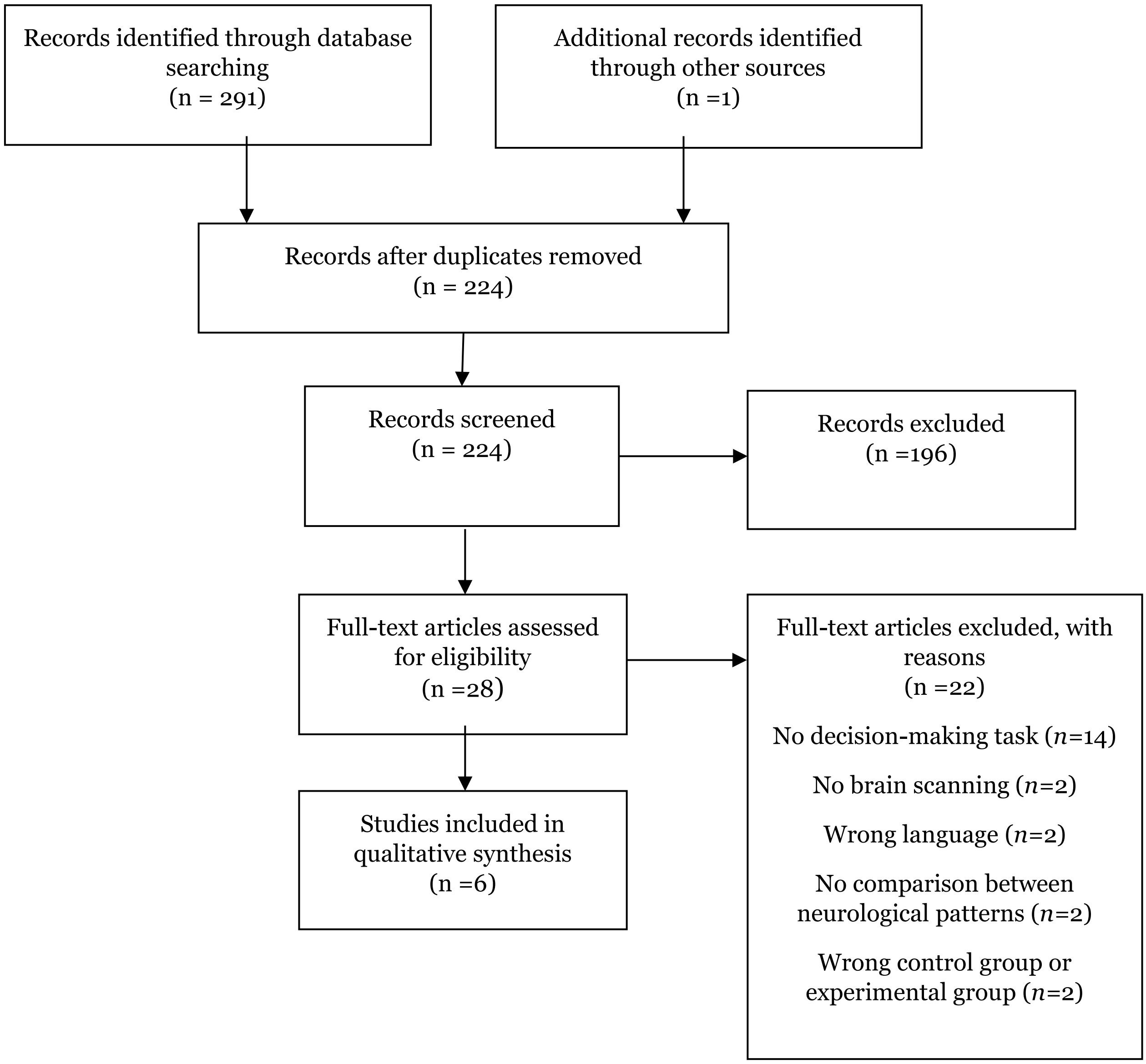
Inclusion and exclusion criteria

The inclusion criteria were that (1) the target populations must be diagnosed gambling or opioid addicts; and that the studies must (2) include a control group, (3) examine neurological activity or structural changes via fMRI, MRI or PET and, (4) in some way, examine decision-making. Studies were excluded if they included participants with (1) Parkinson's disease or (2) dementia.

Data extraction

Data of interest are sample size, mean age of participants, and diagnosis. Regarding the interventions I will look at what kind of task and what measurement tools were used. Finally, I will compare measurements taken (neurological and behavioral patterns) between gambling and opioid addicts and extract authors initial hypothesis and primary results.

Figure 1. Process of selecting articles for the systematic review.



Note. PRISMA 2009 Flow Diagram: standard flow diagram used to document the literature search process. Citation: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and MetaAnalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

Results

The most common finding across studies were decreased activity in the frontal cortex and especially in the orbitofrontal cortex in both gambling and opioid addiction. Behaviorally, results showed that addicts tend to choose the short-term reward above the long-term reward, compared to controls. As the orbitofrontal cortex is mainly involved with decision-making, addicts impaired decision-making ability is explained. These results are consistent with previous research.

Table 1. An overview of included articles and their key results.

Article	**Sample size**	**Mean age**	**Form of measurement**	**Neurological results**	**Behavioral results**	**Conclusion**
(Brevers et al., 2015)	Gambling addicts: (*n*=10) Control: (*n*=10)	Addicts: 34.00 Control: 36.20	fMRI+ decision making task	Choosing the bet option, gambling addicts showed increased activation in the right putamen (striatum) under risk compared to ambiguity, results showed decreased activity in globus pallidus.	Gambling addicts more often choose the bet option in both conditions	Gamblers are less affected by uncertainty compared to controls
(Brevers et al., 2016)	Gambling addicts: (*n*=15) Control: (*n*=15)	Addicts: 24.67 Control: 22.07	fMRI + Iowa gambling task	Results showed that gambling addicts had higher ventral-striatal activation Lower dorsolateral prefrontal and orbitofrontal cortex activation compared to control group	No behavioral difference	Gambling addicts are not affected by risky vs. safe choice
(Dixon et al., 2014)	Gambling addicts: (*n*=12) Control: (*n*=10)	No age presented	fMRI + decision making task	Gambling addicts showed increased activation in dopaminergic pathways while experiencing a big win compared to controls.	No behavioral difference	Shows similarities between drug abuse and gambling addiction

(Lee et al., 2005)	Heroin addicts: (*n*=11) Control: (*n*=10)	Addicts: 29.54 Cntrol:29.05	fMRI + decision making task	Significant activity in the left dorsolateral cortex, the bilateral inferior parietal region and the left middle temporal regions decreased activity were shown in the anterior cingulate cortex	Results showed that heroin addicts were faster to complete the test but did so with more errors	Heroin addicts have impaired impulse control compared to controls
(Ma et al., 2015)	Heroin addicts: (*n*=14) Control: (*n*=14)	Addicts: 37.86 Control: 36.36	MRI + Iowa gambling task	Decreased connectivity strength especially in orbitofrontal cortex, bilateral inferior parietal lobe, bilateral superior frontal gyrus, bilateral paracentral lobe, left parahippocampal gyrus and right middle temporal gyrus	Performance on the Iowa gambling task showed to correlate with number of years of abuse: i.e., the longer abuse the worse performance in the Iowa gambling task	Heroin addicts have a deficit in connectivity strength within the default mode network which disturbs their decision-making ability
(Qiu et al., 2011)	Heroin addicts: (*n*=31) Control: (*n*=24)	Addicts: 37.19 Control: 35.38	Resting state fMRI + Iowa gambling task	Resting state fMRI showed decreased blood flow in the bilateral medial orbitofrontal cortex, bilateral dorsal medial thalamus, bilateral cuneus and lingual gyrus	Addicts prove likelier to select the disadvantageous (higher risk) cards compared to controls	These results could be an explanation why heroin addicts have decreased decision making ability

Gambling studies

Brevers et al. (2015) examined whether grades of uncertainty related to decision making had an impact on behavioral or neurological patterns in gamblers. Each participant in the experiment group met the DSM gambling disorder criteria. Participants underwent a version of the card-deck paradigm developed by Hsu et al. (2005), where they were asked to choose between a bet option, offering a large but uncertain reward, or a safe option offering a low but certain reward, while undergoing fMRI. The bet option had two conditions. Either the probability of reward was known (risky condition) or it was unknown (ambiguity condition). The hypothesis was that uncertainty would not significantly affect gambling addicts regarding risk-taking either on a behavioral or neurological level, compared to controls. Gambling addicts more often chose the bet option in both conditions. Gambling addicts showed decreased activity in the globus pallidus (controls voluntary movement and consciousness, part of the basal ganglia; Javed & Cascella., 2022) during decision making under the risky condition compared to the ambiguity condition. When choosing the bet option, gambling addicts showed increased activation in the right putamen (regulates learning, facilitates and inhibit movement, part of the dorsal striatum and basal ganglia; Ghandili & Munakomi., 2022). The researchers conclude that gambling addicts suffers from decreased cognitive function. This explains their lack of control while gambling. The results indicate that gambling addicts relative to controls suffer from decreased sensitivity to uncertainty, which reduces their hesitation and increases the risk of losing.

Another study by Brevers et al. (2016) examines whether neuronal activity differs between gambling addicts and controls during the Iowa gambling task while undergoing an fMRI scan. Addicts were recruited by self-rating how often they gambled. The hypothesis was that gambling addicts would show stronger brain activity in regions connected to the Iowa gambling task such as the ventral striatum, amygdala and insula, with decreased activation in the dorsolateral prefrontal cortex (executive function: e.g., planning; Hertrich et al., 2021), ventromedial prefrontal cortex (learning and decision-making; Bechara et al., 2000), orbitofrontal cortex (part of the prefrontal cortex, has a central role in decision-making; Rolls., 2000) and anterior cingulate cortex (regulates emotions and reward related functions; Jumah & Dossani., 2021) compared to controls. Results showed that gambling addicts had higher ventral-striatal activation and lower dorsolateral prefrontal and orbitofrontal cortex activation compared to the control group. This suggests that gambling addicts are unaffected by the uncertainty when choosing between disadvantageous and advantageous choices. These results provide evidence for diminished cognitive function in gambling addicts compared to controls.

Dixon et al. (2014) examined whether gambling addicts were affected either behaviorally or neurologically doing a slot-machine task while undergoing fMRI. Level of addiction was tested by using the South Oaks Gambling Screen. Participants were told to play a computerized slot machine and guess how likely they were to win on each trial. Behaviorally, there were no differences between gambling addicts and controls, though there were neurological differences. Compared to controls, gambling addicts showed increased activation in dopaminergic pathways (e.g., the mesolimbic pathway) when experiencing a big win. According to the authors, this increased activation in dopaminergic pathways resembles the effect produced in substance abuse, while not naming a specific substance (Dixon et al., 2014).

Heroin studies

Lee et al. (2005) examined differences in neurological correlates and behavior between heroin addicts and controls. Heroin addicts were recruited from the Native American Research Training Center. Participants were asked to identify which direction an arrow was pointing, and then answer the opposite direction while undergoing fMRI. Results showed that heroin addicts were faster to complete the test but did so with more errors. Addicts showed significant activity in the left dorsolateral cortex, bilateral inferior parietal region (controls movement; Bečev et al., 2021), and left middle temporal regions (language and semantic memory processing; Onitsuka et al., 2004). Decreased activation was shown in the anterior cingulate cortex. These results suggest that heroin addicts suffer from impaired impulse control, which affects their decision-making ability.

Ma et al. (2015) investigated functional connectivity in the default mode network (involving the posterior cingulate cortex/precuneus in the medial parietal lobe, medial prefrontal cortex, and lateral parietal cortex) between heroin addicts and a control group. Participants were diagnosed using the criteria from the DSM. Participants were to provide a urine test that was positive for heroin. Each participant underwent the Iowa gambling task to evaluate their decision-making ability, accompanied by fMRI scanning to evaluate subcortical resting state. Results on the Iowa gambling task and evaluation of resting state fMRI were compared between groups to see if there were any differences. The authors hypothesized that heroin addicts' brain patterns would show abnormalities, especially in the default mode network. The neurological patterns within the default mode network were the same between heroin addicts and controls, but the addicts showed decreased connectivity strength especially in the orbitofrontal cortex, bilateral inferior parietal lobe, bilateral superior frontal gyrus (part of the frontal lobe, involved in self-awareness; Goldberg et al., 2006), bilateral paracentral lobe (pre- and postcentral gyri, involved in motor and sensory functions; Banker & Tadi., 2021; DiGuiseppi & Tadi., 2021), left parahippocampal gyrus (part of the limbic system, involved in spatial memory, encoding and retrieval; Bohbot et al., 2015) and right middle temporal gyrus (part of the middle temporal region). Performance on the Iowa gambling task was shown to correlate with number of years of abuse: i.e., the longer the abuse, the worse the performance on the Iowa gambling task. The authors conclude that heroin addicts show disturbance within the default mode network in connection with decision-making. The question then, is if there is a similar disturbance within decision-making in heroin vs. gambling addicts.

Qiu et al. (2011) investigated neural activity using resting state fMRI to see if neuronal changes in heroin addicts are related to disturbances in decision making. As in Ma et al. (2015), participants were diagnosed using the criteria from the DSM, and had to provide a urine test that was positive for heroin. The Iowa gambling task was used with the standard four-card paradigm: participants were asked to pick a card (A, B, C or D) knowing that each card offered different levels of risk and reward. The addicts proved likelier to select the disadvantageous (higher risk) cards compared to controls. Resting state fMRI showed decreased blood flow in the bilateral medial orbitofrontal cortex, bilateral dorsal medial thalamus (memory and decision-making; Li et al., 2004), bilateral cuneus and lingual gyrus (both part of the occipital lobe, involved in visual processing; Palejwala et al., 2021). There was a positive correlation between performance level on the Iowa gambling task and activation of the ventral medial orbitofrontal cortex. These results explain why heroin addicts have decreased decision-making ability.

Discussion

This review aimed to compare neurological correlates and behavioral similarities between gambling and opioid addicts. My research question was: do gambling and opioid addiction produce similar behavior and similar neurological patterns in the brain while one is making decisions? If they do, is it possible that these addictions reflect a common underlying condition which should be treated similarly?

A primarily neurological similarity was decreased activation in the orbitofrontal cortex, which is highly implicated in decision-making (Brevers et al., 2016; Ma et al., 2015; Qiu et al., 2011). These results are somewhat consistent with Reuter et al. (2005) and Gorzelanczyk et al. (2014), suggesting that both gambling and opioid addiction involve impaired executive control circuits within the prefrontal cortex. Another main similarity is that all the studies included in this systematic review concludes that the addicts they studied have impaired decision-making ability. Regarding the behavioral aspect, Yan et al. (2014) suggest that both gambling and heroin addicts tend to choose the riskier choice compared to controls. This is consistent with this systematic review, in which four studies reach the same result: that addicts choose the riskier choice (Brevers et al., 2015; Lee et al., 2005; Ma et al., 2015; Qiu et al., 2011). This strengthens the suggestion that these addictions cause impaired decision-making ability. As gambling addiction does not involve any substance being added to one's body, it is impressive that these addictions shows similar brain patterns.

Further, Linnet et al. (2011) and Spagnolo et al. (2019) suggest that both gambling and opioid addiction activate striatal regions. Dixon et al. (2014) concludes that gambling addicts have increased activation within dopaminergic pathways that resembles neurological patterns for substance abuse. That said, they do not mention which kind of abuse they have in mind. All three gambling studies showed increased activation in striatal areas, but in the heroin studies, there was no such activation reported. As activation within the ventral striatum supplies one with motivation and pleasure, I expected this to correlate between gambling and opioid addicts.

One possible explanation is that when gambling addicts underwent the Iowa gambling task, the ventral striatum was activated due to the gambling situation. This group experienced a reward and motivational response while gambling. The heroin addicts did not get the same reward response while gambling as this is not as rewarding and motivational as for gamblers. If a heroin addict instead would use heroin, this would probably activate the ventral striatum as being more rewarding. The Iowa gambling task does not seem to be the most suitable task to compare neural correlates within the ventral striatum between opioid and gambling addicts.

By researching more about these addictions and discovering how they are similar and different, treatments can be developed and hopefully be more successful helping addicts be free from their addiction. Successful research within this field would reduce taboos around addiction and give one a chance to ask for help and be rehabilitated. By getting help, one can start recovering physical health, patch up destroyed family bonds and turn one's economic situation onto the right track. Future generations would grow up in healthy families without addiction, decreasing the chance of passing on the addiction to one's offspring. This research contributes to the literature on gambling and heroin addictions, which could in time help in understanding other addictions or even diseases with similar symptoms.

Regarding the society, research about addictions would increase knowledge so that the local care could be better educated and be able to provide accessible help for addicts. Rehabilitating addicts and diminishing the amount of relapse would help society to diminish illegal activity, hospitalization, homelessness, child abuse, and even death. As these things are paid with taxes, it would also be an economic gain for the whole society.

Although this review is a step in the right direction, there are still big obstacles to overcome regarding, e.g., rehabilitation addiction of addicts. One problem is the addict's motivation to being free of the addiction. Even if rehabilitation became more successful, there would still be addicts that either don't think they have a problem or don't have the will to stop the abuse.

Ethical aspects

The voluntary nature of participants' participation could be a problem as addicts may not be in a right state of mind when giving information or choosing to participate. Either way, this could affect their decision-making ability regarding whether they want to participate.

The researchers often offer monetary remuneration (Brevers et al., 2015, 2016; Dixon et al., 2014) for participating. As mentioned earlier, addicts tend to choose fast and effortless ways to maintain their addiction. The remuneration could affect participants' decision whether to participate. One idea would be to leave out remuneration and instead offer: e.g., rehabilitation. The remaining studies (Lee et al., 2005; Ma et al., 2015; Qiu et al., 2011), do not mention anything about remuneration.

Further, how ethical is it to let a gambling addict gamble? As gambling addicts have problems with gambling, the Iowa gambling task could trigger continued abuse. As a result, studies like this could unconsciously encourage the gambling addiction.

Limitations

After writing this thesis, several limitations were discovered. First, I would not have chosen to write about opioids as I discovered during the writing that my knowledge about this subject were limited. Second, I would have changed my search string to be more specific, to find more relevant studies to include in my systematic review; one example is the word "opioids". After filtering all my articles, I discovered that most authors did not use the wording "opioids" in their studies, but instead named the specific drug or simply wrote "substance abuse". This may have decreased my total number of hits when conducting my search. Third, there were a problem concerning the systematic review search. Web of Science resulted in different amounts of hits. This postponed my work and resulted in me having to redo the search and filtering. This may have occurred due to my limited experience performing database searches. Fourth, I had a problem clarifying how Brevers et al. (2015) conducted their study. The authors used the word "risky" for the condition where the probability of reward was known, and the wording "ambiguity" for the condition where that probability of reward was unknown. I found the choice of wording confusing and the article badly written.

I could not find as many similarities between the two groups as I expected. I was hoping for more brain structures in common showing the same activation patterns during decision-making. One explanation could be that, because of the small sample sizes, it is hard to find a proper baseline of activation representing the overall population, as the variation in brain function between individuals is huge. Larger samples would increase the validity of these studies. Another explanation could be that these six articles do not really examine the same thing and are not interested in the same brain regions. By just including studies focusing on the same regions, it would been easier to draw conclusions regarding similar or different brain patterns.

Future research

Research on other related topics such as reward-based behavior and impulsivity could increase knowledge of how to help these addicts. Maybe the two forms of addiction should be treated more similarly to each other. To answer this question, further research within this field is needed. Another way forward would be to compare gambling abuse with a more common substance as marijuana. As this is a psychological addiction just as gambling addiction, how do marijuana affect decision-making or focus compared to gambling addiction? Comparison could be made to investigate neural correlates and behavior between these two addictions.

Conclusion

This systematic review has compared neurological patterns between opioid and gambling addicts related to decision making. My research question was if gambling and opioid addiction produce similar behavior and similar neurological patterns in the brain while one is making decisions, and if they do, is it possible that these addictions reflect a common underlying condition which should be treated similarly? Taken together, the results show decreased cognitive function for both gambling and heroin addicts and consequently impaired decision-making ability, though — the ventral striatum showed no significant activation for heroin addicts as it did for gambling addicts. This suggests that there are indeed similarities between these addictions, but unfortunately the results are not conclusive enough to reach to any conclusion and I can not either reject or confirm my hypothesis.

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