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Virtual reality-induced dopamine reward hypothesis for opioid addiction

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Abstract

While the opioid epidemic continues to plague the globe, scant research exists into the opportunities of virtual reality (VR) therapy for opioid addiction treatment. Furthermore, few to no studies have explored the potential of VR as a dopamine replacement solution for the dopamine deficiency caused by opioid withdrawal. Therefore, this theoretical research article sought to address this research gap by proposing a hypothesis framework involving VR exposure immediately following administration of the tapered opioid medication to help the patient associate the opioid-induced reward experience with the simulation. This method would then compare dopamine levels during VR exposure to corresponding levels 20 minutes following administration of the medication to assess whether the reward memory from the VR experience has the capacity to essentially compensate for dopamine deficiency during opioid withdrawal.

Key words: Addiction; cyberpsychology; neuropsychiatry; virtual reality; non-pharmacological treatment.

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Introduction

As with many situations of addiction, the opioid epidemic disproportionately affects underserved populations. This phenomenon largely stems from a lack of access to addiction management resources and healthcare in general among marginalized communities worldwide.[1] Regarding opioid use in particular, abuse mortality rates rose by 12.4% between 2017 and 2021, primarily in the Americas, and have only worsened with the COVID-19 pandemic. While Europe showed improvement in terms of opioid abuse, Africa and Asia suffered increased chronic disability.[2] Synthetic opioid production in high-income regions has further fostered this epidemic, specifically in resource-scarce regions. Given the role of dopamine in the addictive effects of opioids, a non-pharmacological replacement solution such as virtual reality (VR) could represent a treatment option.

As far as demographics, in the United States, men are more likely to have access to substance use disorder treatment. In this context, while opioid abuse treatment resources have improved for males and lower income populations, racial minorities, females, sexual minorities, and uninsured populations still struggle with access.[3] Particularly as these groups most at-risk for lack of resources for opioid addiction tend to be lower income, facilitating treatment affordability remains paramount. Due to its potential dopamine-agonist benefits, VR could offer a cost-effective treatment solution to consider alongside addiction withdrawal medications for recovering patients who might not have access to sufficient health coverage for prolonged pharmacological treatment.[4] Specifically, this technology could potentially help patients withdrawing from opioids to associate the VR simulation experience with the opioid-induced reward experience, thus supporting opioid dependency reduction.

Literature review

While research exists surrounding opioid addiction risk as well as the uses of VR for mental health, far fewer studies have explored the use of VR for opioid addiction management specifically. Given the financial cost and risks posed by traditional addiction management medications such as Lofexidine, a non-pharmacological option warrants investigation.[5] This article focused on the opioid epidemic due to its devastating global impact, especially among the underserved. Relevant articles and clinical case studies were sourced from the following databases: National Institutes of Health (NIH), Elsevier, JAMA, and Wiley for a comprehensive assortment of opioid addiction and VR-related studies. Inclusion criteria emphasized the following keywords: opioid addiction, dopamine reward system, virtual reality. The majority of studies were literature reviews, and all studies were conducted within the 2020-2026 with outliers in 2012 and 2018. Due to the underrepresentation of research into using VR to help treat opioid addiction, the literature review for this article faced limitations in terms of studies focusing specifically on VR-assisted treatment for this condition.

This literature review was guided by the following parameters in population, intervention, comparison, outcome, and study design (PICOs). However, it should be noted that due to the theoretical nature of this paper, the methodology design for this framework informed by the following literature review is still in its planning stage and must therefore be viewed as a guideline rather than a currently usable framework.

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Population: the target population for this study would be individuals in active recovery from opioid addiction who are entering the medication tapering phase of recovery. The relevant literature included clinical trials involving patients undergoing withdrawal treatment from opioid medications.

Intervention: the aforementioned target demographic would undergo exposure to a VR experience alongside tapering of the opioid medication. While a short-term solution to help distract the patient and provide temporary mood-based relief, VR exposure would also conclude after a fixed time period to prevent compensatory addiction. The associated literature focused on the anxiolytic and analgesic benefits of VR for opioid-addicted users as well as patients using opioids for chronic pain management.

Control/Comparison: similar to the literature exploring the benefits of VR for managing chronic pain in place of opioids, the proposed control methodology would involve comparing patient mood before and after each VR session.

Outcome: while yet to be determined in the absence of clinical trials, the efficacy of VR as a temporary mood enhancer during opioid withdrawal and recovery will be determined using patient surveys prior to and following VR exposure.

Study design: the present study design draws from the literature focusing on observed analgesic and mood-based benefits of VR by assessing patient mood before and after VR use. However, due to the lack of existing literature surrounding VR exposure for opioid mood withdrawal and neurotransmitter involvement in particular, this design should be considered rudimentary.

VR for addiction management

As discussed by Taubin *et al*.,[6] VR has already shown potential benefits as an addiction treatment solution. This study conducted a systematic literature review according to the PRISMA guidelines in PubMed, PsychInfo, and Embase. Studies were included if they focused on addiction treatment using VR and included measures of anxiety, depression, emotional dysregulation, mood, or treatment retention. Taubin *et al*. primarily targeted articles involving VR for nicotine abuse and identified an overall improvement in cravings experienced by participants in the surveyed studies.[6] Notwithstanding, results surrounding the effects of VR treatment on emotional dysregulation and mood were mixed and warrant further investigation, specifically the role of dopamine on mood and emotional state.

Further, Glavak-Tkalić *et al.*[7] assessed the potential of VR in the prevention as well as treatment of substance use disorders. Similar to the findings of Taubin and colleagues,[6] patients undergoing VR treatment in the sources surveyed by this review also demonstrated a decrease in addictive tendencies. Most studies emphasized proximal outcomes (e.g., craving), which often decreased. Still, this study also did not focus on whether this improvement coincided with the use of VR on dopamine levels.

VR as a dopamine-specific agonist

On the topic of neurotransmitters affected by addiction, Theingi *et al*.[8] focused on serotonin and norepinephrine (adrenaline) among in-patients receiving analgesics, as opposed to dopamine which is the neurotransmitter primarily targeted by opioids. Provided the abundance of opioid analgesics, this emphasis makes sense, given that pain itself often causes anxiety which is closely linked to adrenaline. Despite the focal difference, Theingi and colleagues determined that VR treatment indeed proved effective for altering patient mood.[8] This positive effect of VR could benefit investigation into individuals who might be experiencing anxiety from the pain for which they are receiving opioid-based treatment. However, this insight still lacks that focus on the neurotransmitter most affected by the opioid itself.

In fact, the only study identified which touched on the dopamine-agonist effect of VR was not even specifically medicinal in nature. Ochi *et al*.[4] reported an improvement in mood but no change in executive function among participants exposed to a VR gaming experience. Indeed, the researchers even suggested that VR could increase cognitive load, thus emphasizing its risks despite the dopaminergic benefits. Therefore, far more exploration is needed into how VR can improve dopamine levels as a substitute for the dopamine loss during opioid withdrawal with specific attention to users from resource-scarce populations.

VR *vs* opioid treatments

In terms of VR with relation to opioid use, Pandrangi *et al*.[9] compared the efficacy of these two treatment methods in regard to pain management for patients recovering from otolaryngological operations. As far as analgesic success, the VR experience allowed patients to decrease their opioid use by four and eight-hour intervals. However, this study focused on opioid analgesic use for otolaryngological surgery rather than examine the role of dopamine enhancement by VR versus opioids. As a result, the mood-enhancing effect largely responsible for addiction was left unexplored.

Memory of the dopamine reward experience

From a similar standpoint, Fry *et al*.[10] examined the role of dopamine in reward memory for future learning toward adaptive actions in the present. This study used chemogenetic and optogenetic manipulations to confirm dopamine cells as required and sufficient for mediated memory devaluation. This memory retrieval showed dopamine release in the nucleus accumbens. As predicted by the researchers' computational modeling data, findings demonstrated a critical role for dopamine in encoding predictive representations of reinforcement sensory features. While this study also did not involve VR use, the neurobiology and neuroanatomy of the dopamine reward system provided helpful insight into how dopamine helps drive memory toward beneficial actions. This insight could help inform how a memory of the opioid-induced reward experience associated with a specific VR experience could train the brain to produce dopamine in response to that simulation instead of the opioid medication itself.

Perhaps most relevant to the present article, Barr[12] discussed the use of VR as a Pavlovian solution to help condition patients to dissociate their in-hospital environment from their outpatient environment, thus separating the urge to continue taking opioid analgesics for too long beyond their hospital stay. However, this article was closer to a proposal for further research as opposed to a clinical study, leaving a clinical study yet to be conducted. Moreover, Barr's proposal did not focus on replacement of specific neurotransmitters, such as dopamine or others impacted by VR.[11]

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Table 1 illustrates the contributions of each study included in the literature review, including the importance of conditioning based on the memory of the dopamine reward experience for uses ranging from mood enhancement, analgesic management, and improved executive function.

Framework methods

Thus, this paper proposes a speculative pathway framework wherein recovering addicts would undergo intermittent VR sessions to develop the memory of dopamine reward as a replacement therapy. The second stage would involve recording fluctuations in mood levels *via* qualitative mood survey during VR exposure *vs* periods of exposure to the tapered opioid medication. While not capable of measuring exact dopamine fluctuations in the nucleus accumbens, these tests could be used as a working approximation to assess for patterns between changes to dopamine during the VR experience versus the opioid.

The survey

Due to the non-urgent nature of this mood assessment, the survey would employ the Hospital Anxiety and Depression Scale (HADS) to measure fluctuations in patient mood before and after each VR session.[12] The survey itself could use questions such as:

"How are you feeling?" to assess for an overall change in mood.
"Do you feel as if you are slowed down?" to assess depression.
"Do you feel restless?" to assess anxiety.

The third part of the framework would entail routine VR exposure immediately after administration of the tapered opioid medication so as to help the patient associate the VR experience with the dopamine-enhanced state induced by the opioid. Table 2 shows the two stages of the proposed replacement framework.

In addition to the potential dopamine fostering benefits of this exposure, the specific VR experiences could also be tailored to the individual's preference so as to help induce a specific simulation(s) with which the individual would associate the positive (dopamine reward system). This customization could be achieved by testing the patient with various audiovisual experiences in terms of brightness of visuals and loudness of sounds. The brightness (measured in lumens, lm) and loudness (measured in decibels, dB) would then be matched to the corresponding mood spike for the individual in question. Figure 1 illustrates the VR headset and corresponding trial flow proposed by this framework, detailing both the headset design and sequence of trial phases from opioid administration through VR exposure.

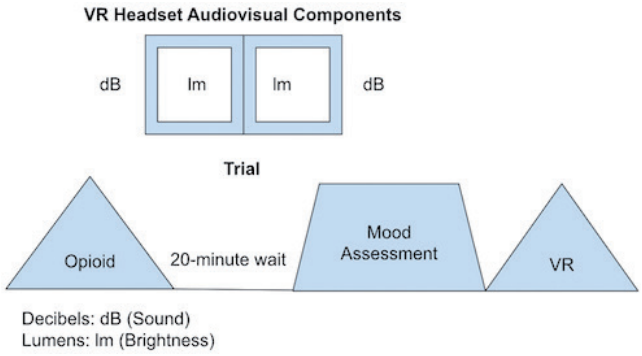
In the proposed scenario, clinical trials would be conducted to test the efficacy of this framework in a real-world setting. Such a trial would employ a VR headset equipped with audiovisual output set to adapt to the wearer's cues with a brief qualitative assessment to check on patient mood performed 20 min (upper end of the average timeframe for onset of the opioid "high" from oral administra-

Table 1. Selected literature.

Article	Contribution
Fry BR, Russell N, Fex V, *et al.* (2025). Devaluing memories of reward: a case for dopamine.	Explores the importance of the memory of dopamine reward which relates to the memory of the dopamine reward experience as a tool for evoking such memories using non-pharmacological treatment such as VR
Barr A (2026). Virtual reality-paired opioid analgesia as contextual prophylaxis against iatrogenic opioid addiction: a hypothesis.	Explores the potential of combining opioid analgesic with VR use to limit the reward experience with the VR experience, similar to leveraging the association between the opioid "high" and the concurrent VR experience
Ochi G, Kuwamizu R, Fujimoto T, *et al.* (2022). The effects of acute virtual reality exergaming on mood and executive function: exploratory crossover trial.	Investigates the benefits of gaming-specific VR for mood enhancement and executive function improvement
Taubin D, Berger A, Greenwald D, *et al.* (2023). A systematic review of virtual reality therapies for substance use disorders: impact on secondary treatment outcomes.	ses a systematic literature review to study the general benefits of VR Utherapies for substance abuse though without a focus on opioids
Glavak-Tkalić R, Šimunović M, Perić Pavišić K, *et al.* (2025). Virtual reality in prevention and treatment of substance-related disorders: a systematic review of randomized controlled trials.	Uses clinical trials to assess the efficacy of VR therapies in substance use disorders
Theingi S, Leopold I, Ola T, *et al.* (2022). Virtual reality as a non-pharmacological adjunct to reduce the use of analgesics in hospitals.	Similar to the present article, focuses specifically on the non-pharmacological advantages of VR to reduce dependence on opioids for pain management among in-patients
Pandrangi VC, Shah SN, Bruening JD, *et al.* (2022). Effect of virtual reality on pain management and opioid use among hospitalized patients after head and neck surgery: a randomized clinical trial.	Uses a case study to investigate the usefulness of VR versus opioids for pain management following surgery on a specific area of the body

Table 2. Virtual reality dopamine replacement framework.

Stage 1 (virtual reality exposure)	Administer virtual reality exposure following opioid administration
Stage 2 (mood assessment)	Administer qualitative mood assessment during virtual reality exposure *vs* immediately after opioid administration



Virtual reality headset design and trial flow.

tion) following ingestion of the opioid tablet and then performed again immediately after the VR experience.[13] The researchers would then compare the dopamine levels from each sample.

Crucially, while Barr[11] used the memory of the VR experience to help patients dissociate from the opioid reward experience, this study could potentially run the risk of the opposite effect in substituting users' craving for the opioid reward with the similar dopaminergic effect of the VR experience. Therefore, clinical studies could employ a tapered experience wherein the user's exposure to the VR therapy would be incrementally decreased alongside the opiate administration to help decrease the risk of dependency on the VR experience. Specific quantities such as the VR exposure incremented tapering time can be determined as needed.

Conclusions

While many studies have focused on the benefits of VR as a treatment option for mental health, less research exists surrounding VR's opportunities for addiction treatment. Further, to the author's knowledge, no studies have explored the potential of VR as a replacement option for a neurotransmitter imbalance induced by opioid medications. In light of the longstanding global opioid epidemic, this paper proposed VR as a dopamine replacement solution for individuals recovering from opioid addiction.

Limitations and future studies

In addition to the framework limitation noted above, this article has several limitations, namely, the lack of existing literature focusing on neurotransmitter replacement theory in any context, let alone specifically opioid addiction. Therefore, the methodology used for the VR device design and clinical trial plan for the proposed replacement framework could likely be improved with further research into how to measure neurotransmitter fluctuations in real time. Additionally, the routine mood testing among patients recovering from addiction could prove invasive in some situations.

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