https://doi.org/10.48047/AFJBS.7.10.2025.200-207

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Investigating the impact of virtual reality on individuals facing substance addiction throughout their treatment process: a narrative review study

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Volume 7, Issue 10, 2025
Received: 14 July 2025
Accepted: 25 Sep 2025
Published: 13 Oct 2025
Doi :10.48047/AFJBS.7.10.2025.200-207

Drug addiction is a chronic relapsing disorder(1) and one of the most critical public health problems in the world(2) that affects brain function and behavior, resulting in an inability to control drug use(3). The consumption of substances to achieve feelings of euphoria dates back to ancient history; the Sumerians consumed opium for happiness, while Native South Americans began chewing coca leaves for energy around 3,000 years ago (4).

Drug addiction is closely linked to behavioral and social factors, which are crucial components of the disease. This includes addiction to tobacco, alcohol, and both direct and indirect drug use, leading to 11.8 million deaths globally each year. According to the Global Burden of Disease Study, this figure exceeds the number of cancer deaths and accounts for one-fifth of all global mortality(1). Genetics account for 40 to 60 percent of addiction risk, and social and environmental factors play a critical role in this chronic disease(4). The impact of this issue is compounded by stressors such as family breakdown, unemployment, and job-related stress(3). As rates of addiction continue to rise, a variety of pharmacological and non-pharmacological treatments have been developed to effectively address the associated problems

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The most effective treatment approaches involve biological, behavioral, and social elements. According to the latest scientific advances, managing drug-addicted patients requires a personalized strategy(1). Treatment is linked to reduced mortality, lower rates of viral transmission, fewer complications from intravenous drug use, greater retention in treatment, and enhanced overall health and well-being(6). There is an urgent need for further research to enhance both assessment and treatment strategies. It is particularly important to explore new treatment modalities for patients who do not find relief from traditional therapies. By investigating these alternative approaches, we can better meet the diverse needs of all patients(2). Recently, researchers have focused on using virtual reality to treat psychiatric disorders, such as drug addiction(2, 7). This approach enables the collection of physiological and subjective measures of substance use cravings in an experimental setting that mimics real-world conditions(8). Virtual reality is emerging as one of the key technological breakthroughs that is increasingly accessible and easy to use(7). Virtual reality is a technological innovation that generates a three-dimensional environment, closely mimicking the real world through visual, auditory, and tactile sensations. Users can interact with this immersive environment physically by using specialized electronic equipment(9). It can convey visual, auditory, and other sensory experiences to users, immersing them in an imaginative environment(9).
The equipment facilitates comprehensive engagement with the environment, thereby eliciting immersive emotions and experiences. Due to its high ecological validity, this technology surpasses traditional stimuli, such as images and videos, in its capacity to activate addictive memories. Considering the limitations of prior research and the rapid advancements in the realm of virtual reality (especially regarding its applications in drug addiction) there exists a pressing need for further investigation into the various facets of this innovative treatment modality for individuals with substance dependence undergoing therapy.

Methods:

This research is a narrative review study that was conducted in 2025 after obtaining the ethics code IR.ABADANUMS.REC.1403.115 from the Ethics Committee of Abadan University of Medical Sciences. Data collection involved searching for the keywords (Virtual Reality OR Virtual Reality Treatment OR VR) AND (Drug Addiction OR Drug Abuse OR Substance Abuse OR Substance Addiction OR Alcohol OR Cocaine OR Cannabis OR Opioid OR Methamphetamine) in international databases such as PubMed, Science Direct, Scopus, and Google Scholar, as well as in local databases including SID, Magiran, and Iran Medex using Persian keywords. The inclusion criteria were quantitative or review articles with full-text accessibility, published in Persian or English, and covering the time period up to 2025.

Screening of articles was carried out in three stages and based on the PRISMA process.
The required data were extracted using a checklist including study type, study time, and results.
In order to increase the robustness of the research methodology and assess the quality of the articles, another researcher separately reviewed the articles in terms of title, abstract, introduction, methods, and results. First, articles that were not relevant to the topic or were duplicated in different databases were eliminated. Initially, the abstracts of the articles and their objectives were examined to exclude irrelevant items from the study. Subsequently, the texts of the remaining articles were reviewed, removing any content that did not align with the study objectives. Out of

the 65 studies identified, 44 were excluded, resulting in 21 articles that were thoroughly reviewed. (Fig. 1)

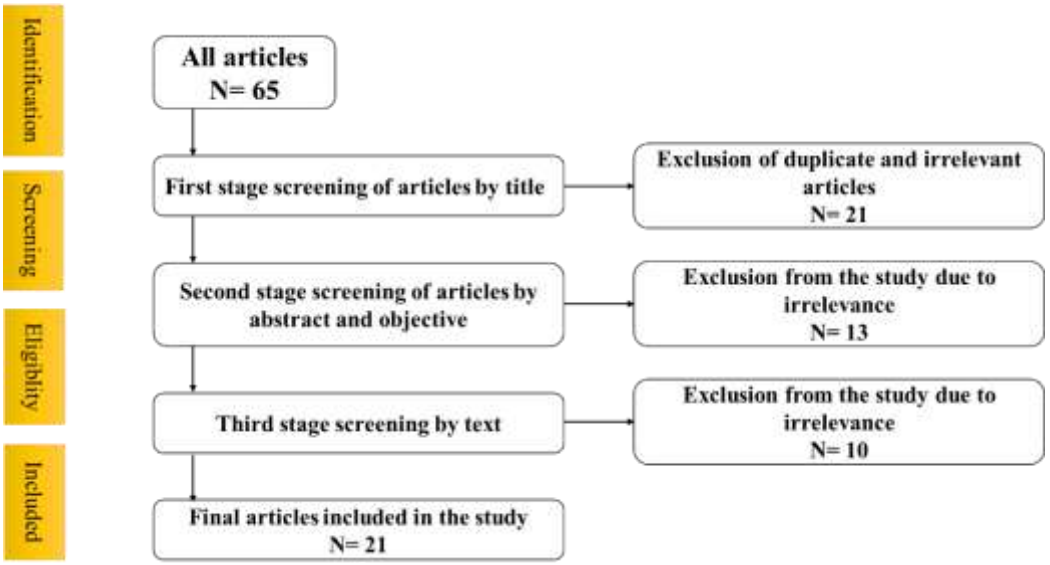

Fig 1. PRISMA diagram of the study selection process. It illustrate the number of records identified, included, and reasons for exclusions.

Results:

Research studies utilizing electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) indicate that individuals with addictive disorders demonstrate diminished activity in the prefrontal cortex relative to control subjects. These deficiencies are correlated with psychophysiological parameters and are subject to modification during the course of virtual reality (VR) therapy.

Using embedded neuropsychological assessments, virtual reality simulations can reliably and accurately evaluate visual processing speed, decision-making, and addiction-related cues. This includes attentional bias toward visual and olfactory stimuli, as well as thoughts concerning substance use compared to neutral cues(10). In an intervention study using VR simulation-based cognitive behavioral therapy, it was found that drug users, including those using marijuana, cannabis, and other smoking substances, paid more attention to visual and olfactory cues and experienced increased thoughts about drug use in cue-rich conditions compared to neutral conditions(11, 12).

In VR simulations, animated cues related to substance use, such as lighting a cigarette, suggesting drug use to the participant, and observing a cigarette burning in an ashtray, can significantly affect the participant's autonomic system compared to non-verbal cues(13). Environmental pressure and social circles, such as groups of friends who use drugs at parties or in public, can heighten a person's cravings for drugs(7). The most prominent of these effects are: increased heart rate(13-15), increased skin conductance(14, 16), Galvanic Skin Response(17), and changes in pupil size (14). However, if a person is repeatedly exposed to these cues, the psychophysiological skin conductance response gradually decreases (16). In these patients, the galvanic skin response proves to be a more effective tool than electroencephalogram (EEG) signals for differentiating between patients and controls (17). This evidence may stem from emotional arousal, perceived stress,

anxiety, and depressive states that drug users experience during VR simulations in treatment (18-22). The use of animated simulations, along with the inclusion of social situations, can enhance both physiological effects and emotional responses, resulting from a deeper sense of immersion. One study indicated that VR simulations linked to cocaine use resulted in an increased heart rate and a decrease in happiness among individuals with the condition (23). Similarly, a study focused on individuals with methamphetamine use disorder (MUD) demonstrated a notable rise in skin conductance when compared to neutral stimuli(17).

Mazza:

In patients with MUD, gamma EEG bands in the right dorsolateral prefrontal cortex are diminished in a methamphetamine-cue virtual reality setting compared to neutral conditions (24). These EEG band alterations predict skin conductance levels and are linked to reduced impulse control, closely associated with addictive behavior (25).

VR-based interventions can more effectively identify risky drug use situations, recognize dysfunctional thoughts, enhance self-efficacy and confidence in quitting drug use, and reduce the frequency of drug use during treatment compared to imaginary exercises(26, 27).VR simulations are effective tools for examining the cognitive processes related to drug use. They allow researchers to measure the connection between various symptoms associated with craving. Additionally, VR can be invaluable for studying cognitive impairments and related factors in individuals struggling with drug addiction (28). Research shows that VR simulations are particularly effective for individuals experiencing high cravings compared to those with lower cravings. Additionally, the studies referenced earlier demonstrate that VR-assisted therapy outperforms traditional therapies and can effectively complement other treatment methods. A significant advantage of this therapeutic approach is its capacity to personalize treatment for each individual, which was also highlighted in the conducted studies (10).

Discussion:

The available research indicates that VR environments are an effective technology for inducing drug cravings and enhancing physiological responses, emotional states, attention, cognition, and brain activity(29). Compared to laboratory, clinical, and traditional methods, VR environments offer better effectiveness due to their ability to create more immersive simulations with a stronger sense of presence (30). Additionally, VR experiments enable the direct recording of behaviors within the virtual reality display system (31). Therapeutic interventions may be more effective in VR environments because they present more realistic high-risk situations (11). VR simulations offer the ability to easily switch between different scenario problems, enabling the creation of varied scenarios within a single environment tailored to the patient's needs, which is not feasible with traditional methods(28). Another significant benefit of incorporating VR into cognitive behavioral therapy is the straightforward access to stimuli, emotions, and dysfunctional behaviors, particularly for highly rational individuals (26). VR technology also enhances personalized medicine by readily adapting to the symptoms of each individual. Even if future studies demonstrate that VR is as effective as traditional methods, it may still provide advantages such as lower costs, greater usability, shorter test durations, improved confidentiality, and enhanced safety (32). Like other technologies, VR is continuously evolving, leading to the development of better and more affordable solutions for clinicians and researchers.

Another potential issue with VR is cybersickness (26), where conflicting signals are sent to the brain, resulting in nausea, vomiting, and dizziness for the participant. Research in this area is limited, and it is recommended that future studies give more attention to this problem (33, 34). In many studies conducted on substance users, the effects of VR have only been measured through physiological signs such as heart rate and skin resistance, while other indicators, including blood oxygen levels, hormonal changes, and additional physiological variables, have not been explored (35). In some cases, no significant differences were identified in examined data like EEG and ECG, which might be attributed to the small sample sizes (36). Thus, it is recommended that future studies involve a larger participant base. Furthermore, VR experiments should incorporate more realistic sensory experiences such as touch and enhanced interactions to improve realism.
One weakness of existing studies is the lack of biochemical screening to confirm the absence of other drugs and substances before participants enter the trial. Participants might have used additional substances before or during the intervention, and it's possible that they did not share this information during the interviews. Future studies should ensure these substances are absent from screening before entering trial sessions. Additionally, utilizing VR in drug abuse research facilitates the identification of symptoms and the delivery of coping skills-based interventions. This method allows for a more personalized treatment strategy that addresses each patient's unique needs and skill deficits. Moreover, utilizing VR in substance abuse research significantly enhances our ability to identify symptoms and deliver effective coping skills interventions. This strategy ensures a personalized treatment approach that directly addresses the unique needs and skill deficits of each patient, leading to more successful outcomes (10).

Limitations:
Further research is essential to explore various genders, ethnicities, and age groups, ensuring the generalizability of findings. Historically, addiction studies have primarily centered on men, which results in the significant neglect of women and poses a major problem in this field (37). While many studies employing VR technology have focused on pleasant environments, they have largely ignored stressful situations that are known to trigger drug use. Hence, future research must also consider these negative circumstances. Additionally, the impact of VR usage on neural parameters related to addictive behaviors, including cortisol, vasopressin, and oxytocin, remains unclear. Only a small fraction of studies utilizing VR technology have reported changes in neuroendocrine parameters, highlighting the need for further investigation in this area(38, 39).

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