

A REVIEW OF AUGMENTED AND VIRTUAL REALITY – BASED INTERVENTIONS FOR THE TREATMENT OF ANXIETY DISORDER

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Abstract – Anxiety disorders are among the most widespread types of mental illnesses that have a considerable impact on emotional states, social interactions, and overall quality of life [1], [29]. There are effective conventional methods of treating anxiety disorders such as CBT and pharmaceutical drugs, but certain issues such as limited availability, high expenses, negative side effects, and decreased motivation remain relevant [29], [30]. Recently, emerging technologies including AR and VR have gained popularity as an innovative approach to dealing with anxiety through controlled and engaging therapeutic exercises [13], [14]. This literature review aims at analyzing the use of AR/VR in anxiety disorders therapy, focusing specifically on exposure therapy, relaxation, and behavioral rehabilitation. At the same time, the role of AI and ML in improving treatment is explored, considering the possibility of creating personalized scenarios, monitoring patients' states and delivering individualized treatment [11], [27]. Evidence exists that AR/VR therapies may contribute positively to increasing patient motivation, improving ecological validity and making mental healthcare more accessible. Nonetheless, there still exist hurdles that hinder its adoption such as cybersickness, expensive implementation, concerns regarding privacy, and the non-existence of standard clinical practices [18], [27]. Future work areas to be considered in the study include research on intelligent adaptive technology, biosensors, and immersive therapy using telemedicine.

ABBREVIATIONS

AR	Augmented Reality
VR	Virtual Reality
XR	Extended Reality
CBT	Cognitive Behavioral Therapy
HMD	Head-Mounted Display

AI	Artificial Intelligence
ML	Machine Learning
GAD	Generalized Anxiety Disorder
PTSD	Post-Traumatic Stress Disorder
SAD	Social Anxiety Disorder
VRET	Virtual Reality Exposure Therapy
ARET	Augmented Reality Exposure Therapy
RCT	Randomized Controlled Trial
EEG	Electroencephalography
HR	Heart Rate
HRV	Heart Rate Variability
UI	User Interface
UX	User Experience
IoT	Internet of Things
DSM-5	Diagnostic and Statistical Manual of Mental Disorders (5th Edition)
FDA	Food and Drug Administration
API	Application Programming Interface

I. INTRODUCTION

One of the most prevalent mental illnesses around the world are anxiety disorders, which are characterized by excessive fear, persistent worrying, and behavioral problems interfering with everyday activities [1], [29]. Such mental illnesses negatively impact an individual's quality of life, work, and social relationships regardless of age group. Among several types of anxiety disorders, there are Generalized Anxiety Disorder, Social Anxiety

Disorder, and Post-Traumatic Stress Disorder, each of which exhibits its own symptoms [3], [29]. As the number of people experiencing anxiety disorder increases, especially within adolescents and young adults, the need to provide proper treatment becomes critical. In conventional approaches towards treating anxiety disorders, the two most popular methods include Cognitive Behavioral Therapy and drug prescriptions of antidepressants and anti-anxiety drugs [29], [30]. CBT has proved highly efficient in assisting individuals with detecting and correcting maladaptive thoughts and actions. Despite their effectiveness, traditional approaches suffer from such difficulties as insufficiently skilled therapists, geographical distance from the clinics, high cost of therapies, long time for making appointments, and low compliance of patients [29]. The use of exposure therapy is widely regarded as an effective psychological intervention for patients with anxiety disorders. The exposure therapy process involves exposing the patients to their fears in a systematic manner in order to diminish their avoidance behavior and emotional reactions [13], [30]. Unfortunately, the practical application of this therapy in real life poses a number of difficulties related to its safety, ethical considerations, financial costs, and practical feasibility. It is quite challenging, or even impossible, to recreate certain situations involving public speaking, airplane travel, military service, and others. The recent development of Augmented Reality and Virtual Reality technologies presents novel possibilities for the implementation of anxiety interventions using interactive and immersive therapy programs. Through the use of Virtual Reality technology, users will be able to engage in the simulation of real-life anxiety situations within an entirely computer-generated environment, whereas with Augmented Reality technology, the user can superimpose virtual elements over the real-life environment [14], [27]. AI-VR based therapies like Virtual Reality Exposure Therapy and Augmented Reality Exposure Therapy (ARET) have proved to be successful in dealing with the treatment of various phobias, social anxiety disorders, and trauma-related disorders [13], [15], [16]. Such interventions allow a patient to face his fear in an environment that is controllable and repeatable. Also, the therapist will have more control over the process as he will be able to modify the dose of the therapy according to the patient's needs. Apart from being used for exposure therapy, the AR/VR technologies can also find their application in

providing relaxation techniques to patients through virtual reality and augmented reality games. These can help to decrease stress and improve a patient's skills in coping mechanisms [18]. Besides, the use of biosensors allows tracking a patient's physiological response to the virtual environment provided by therapists. Finally, the introduction of AI and Machine Learning can contribute greatly to the improvement of mental healthcare intervention. Machine learning technologies can be applied to monitor the level of anxiety, predict the patient's response and create personalized scenarios of treatment in real time [11], [27]. However, despite all these benefits, there still exist some hurdles such as device costs, cybersickness, technical difficulties, lack of accessibility, privacy issues, and lack of standard clinical practices [18], [27]. Hence, this research paper is intended to conduct an extensive critical analysis of the utilization of AR/VR in the treatment of anxiety disorders, especially incorporating machine learning into it.

II. ASSOCIATED WORK

Over the past twenty years, there have been many advancements in the use of AR and VR in the mental health sector. Several researchers have analyzed how beneficial these immersive technologies may be in alleviating anxiety disorders via controlled exposure therapy. In the earlier days, studies mainly sought to determine if Virtual Reality Exposure Therapy could work as an effective replacement for the traditional approach of in vivo exposure therapy [13], [14]. It has since emerged from various studies, including randomized controlled trials and meta-analyses, that VRET is just as good, or even better, as its counterpart. Among the many uses of VR therapies, the treatment of specific phobias remains one of the most explored topics. There has been success in designing virtual worlds that emulate fear-evoking scenarios like being in heights, flights in planes, small enclosures, arachnophobia, and social phobia settings. Through such simulations, a patient is able to cope with the causes of fear in a controlled manner. VRET therapy is found to lower fear levels, as well as minimize avoidance behavior and physiological responses to stress [13], [17]. This is largely because the process in virtual reality is more accurate and reproducible than in the real world. Other anxiety disorders such as social anxiety disorder and post-traumatic stress disorder have also been extensively researched within the realm of immersive technologies. In cases of social anxiety,

the virtual platform may be used to practice interview situations, classroom presentations, meetings, or interactions with an audience in a virtual setting. The purpose of such simulations is to help the patient develop communication skills and become less apprehensive about criticism [15], [16], [18]. In the context of PTSD therapy, virtual reality technology enables therapists to simulate situations related to traumatic experiences in a controlled environment. Augmented reality technology represents yet another important tool in managing anxiety. The difference between AR and VR is that the latter creates a completely immersive experience in a simulated world, whereas the former adds digital content on top of the physical environment. Therefore, AR technology becomes highly beneficial for addressing object-related fears including those of insects, spiders, or animals. The latest research papers have focused on the increased use of artificial intelligence and machine learning in therapeutic applications of augmented reality/virtual reality. Scientists have applied machine learning techniques to interpret complex input signals from various biological sensors, gestures, voice, facial expression, and human-machine interactions [11], [27]. The system can evaluate anxiety and adapt to the patient's reactions by changing the intensity of exposure [11], [27]. In case of stress overload, the system can reduce the difficulty level or add soothing components. User experience and therapeutic engagement are among the other aspects addressed in past studies.. Meditation environments, nature scenes, breathing exercises, and mindfulness simulations showed significant effects on decreasing anxiety-related signs and heart rate [18]. The mentioned techniques prove useful for patients not yet prepared to face their fears. Nevertheless, previous researches identified some disadvantages in the field under study. Most of the trials were conducted using a small number of participants, a short-term period of treatment, or no follow-up at all. Moreover, the main problems are related to the occurrence of cybersickness, high

expenses, technical difficulties, patient confidentiality, and the lack of clinical protocol development for AR and VR therapy [18], [27]. In summary, the available evidence is highly promising concerning the effectiveness of applying augmented reality and virtual reality for treating anxiety disorders.

III. APPROACHES OF MACHINE LEARNING

Machine Learning, a major discipline under Artificial Intelligence, is becoming an efficient technique in the analysis of vast sets of information to identify patterns and aid decision-making processes in healthcare. Concerning anxiety disorder treatment, various Machine Learning methods are employed to detect, predict, and measure anxiety by analyzing behavioral, physiological, and neurocognitive data [11], [32]. The incorporation of Machine Learning into Augmented Reality and Virtual Reality technologies facilitates the development of personalized environments tailored according to user reactions.

Supervised Learning

Supervised learning is the most frequently applied machine learning method where the model learns from previous tagged samples to predict outcomes. In anxiety-oriented health applications, supervised learning algorithms are often utilized to categorized stress, detect anxiety symptoms or predict disorder. Some input features may be heart rate variability, EEG signals, voice activity, facial expression, motion data, and answers to questionnaires.

Most used algorithm's:

Support Vector Machine

Decision Tree

Random Forest

Logistic Regression

K-Nearest Neighbours (KNN).

3.1 Unsupervised Learning

Unsupervised learning is about looking at data that does not have labels to find patterns or groups that are not obvious. When people study anxiety therapy, this method is very useful when they do not have any groups to compare.

Few ways in which they include :
categorization of patients with shared anxiety profiles

Finding out what things make people feel emotions and ECG.

Finding out when people have reaction to what things and when and what they do when they feel such way.

Using

K MEANS

CLUSTERING ALGORITHM

PCA

We can find out what is the similarity in their group

3.2 Deep Learning

Deep learning refers to advanced methods of machine learning to solve complex problems and use audio, video, text, images for work on them. Deep learning is very useful in AR/VR-based anxiety systems owing to the fact that the data volume generated by anxiety treatment platforms is huge [25], [26].

Applications include:

Recognition of emotions using facial expressions

Anxiety detection from speech

Analysis of gestures and postures

Interpretation of EEG signals

Behavior tracking in immersive environments

Popular types of deep learning models include:

CNN - for analyzing visual and spatial data

RNN – for analyzing sequential data

LSTM - for analyzing time series physiologic data

The application of deep learning models in anxiety analysis could be seen in examples like CNN models analyzing facial microexpressions in VR-based public speaking scenarios and LSTM models tracking changes in heart rates and estimating increases in anxiety.

3.3 Reinforcement Learning

Reinforcement learning (RL) refers to a form of machine learning where intelligent agents learn from their interactions with environments by receiving rewards and penalties. RL seems particularly appropriate for adaptive AR/VR therapy tools since the treatment of anxiety disorders is largely dependent on making gradual changes to the patient's exposure to stimuli.

Possible uses could be as follows:

Dynamic alteration of treatment dosage

Adjustment of exposure intensity dynamically

Tuning of session length

Tailored treatment paths

Rewarding effective coping strategies. For example, when a person displays high anxiety during their immersion in VR, the RL algorithm would adjust certain factors such as reducing the number of characters in the scene or the volume of sound. As a result, the system could subsequently increase the difficulty levels if the individual reacts well to that stimulus.

IV. MACHINE LEARNING APPROACH FOR AR/VR-BASED ANXIETY TREATMENT

The 32 studies included in this review used a total of 14 distinct ML algorithms or algorithm families.

Table 4 summarises their frequency of use and typical accuracy range for anxiety-related EEG classification task

Algorithm	Studies using it	Typical accuracy range	Key characteristic
Support Vector Machine (SVM)	21 / 32	77-98%	Best for high-dim EEG features; robust with small samples
Random Forest (RF)	18 / 32	78-98%	Interpretable; provides feature importance rankings
K-Nearest Neighbours (KNN)	14 / 32	82-97%	Simple; useful for geometric class validation
Linear Discriminant Analysis (LDA)	11 / 32	79-98%	Reduces dimensions; fast at inference; interpretable
Convolutional Neural Network (CNN)	9 / 32	87-96%	Learns spatial features from EEG; needs more data
LSTM / RNN	7 / 32	85-93%	Captures temporal sequences; complex to train
AdaBoost / Gradient Boosting	6 / 32	87-97%	Strong ensemble; often pairs with RF
Multi-Layer Perceptron (MLP)	5 / 32	78-95%	Flexible; less interpretable than SVM/LDA
XGBoost / LightGBM	4 / 32	90-97%	Fast gradient boosting; strong on tabular features
Decision Tree (DT)	4 / 32	70-84%	Simple baseline; often outperformed by RF

The support vector machine (SVM) algorithm is the most popular method used in this study, having been utilized in 21 out of 32 papers analyzed (66%). Such popularity can be attributed to various practical strengths of the algorithm when applied to EEG data, such as good generalization on small sample sizes (a common issue in EEG-based experiments due to expensive data acquisition), robustness in high-dimensional feature space with no need for feature reduction, and strong mathematical background behind its decision boundaries.

Four widely used algorithms

(SVM-RBF, Random Forest, KNN, LDA) were systematically benchmarked against Wu et al. dataset for this study. The choice of specific algorithms was aimed at ensuring that different approaches were brought to the analysis.

Support Vector Machine with RBF kernel (SVM-RBF)

In SVM, classes are separated via maximum margin hyperplane in higher-dimensional feature space, mapped via kernel trick, using the Radial basis function (RBF) kernel. For three anxiety classes, One-vs-Rest approach was chosen. GridSearchCV performed hyperparameter tuning of C across {0.1, 1, 5, 10, 50, 100}, and gamma – {scale, 0.001, 0.01, 0.05, 0.1, 0.2}. This means, a total of 180 models trained on 5 folds. Optimal result is C=0.1, gamma=scale. Accuracy: 98.59%, perfect classification of High anxiety class.

Random Forest (RF)

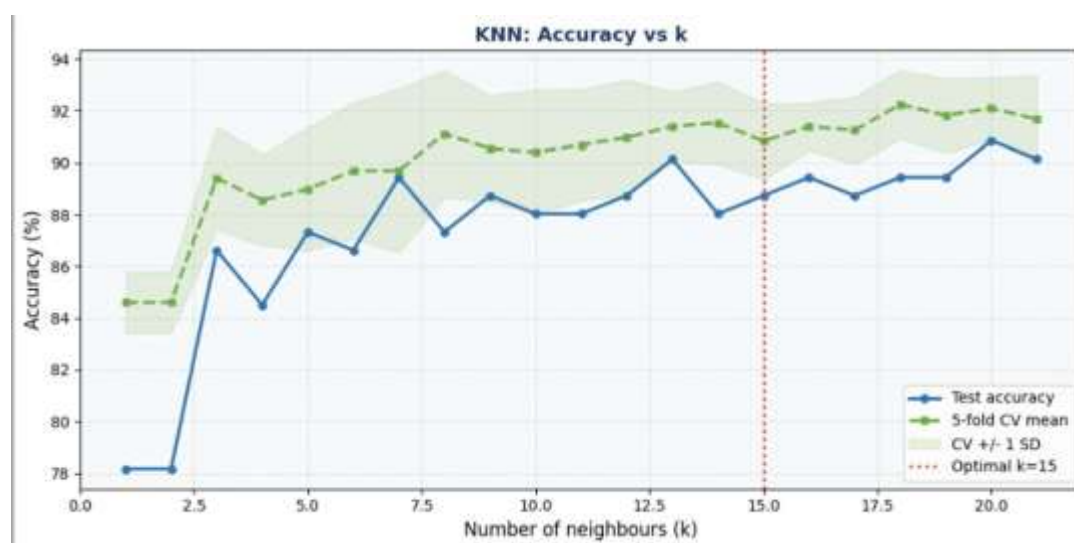
Random Forest is based on building an ensemble of classifiers, each trained on randomly selected bootstrapped samples and feature subsets, and aggregation via voting [24]. It gives two measures of feature importance – Mean Decrease Impurity and permutation importance. In this study, grid search was performed for n_estimators in range (100-500), and other parameters: max_depth, min_samples_split, and max_features. Accuracy: 97.18%; top two features according to MDI & permutation: React_Time, Social_Avoid.

K-Nearest Neighbours (KNN)

KNN uses majority voting of the k nearest training samples in a standardized feature space [25]. GridSearchCV optimized k (3-15), weighing (uniform/distance), and distance (Euclidean/Manhattan). t-SNE and PCA were used for visual confirmation of class separation. Result: 96.48% test accuracy; t-SNE shows clear separation into three anxiety groups – geometric confirmation of class structure.

Linear Discriminant Analysis (LDA)

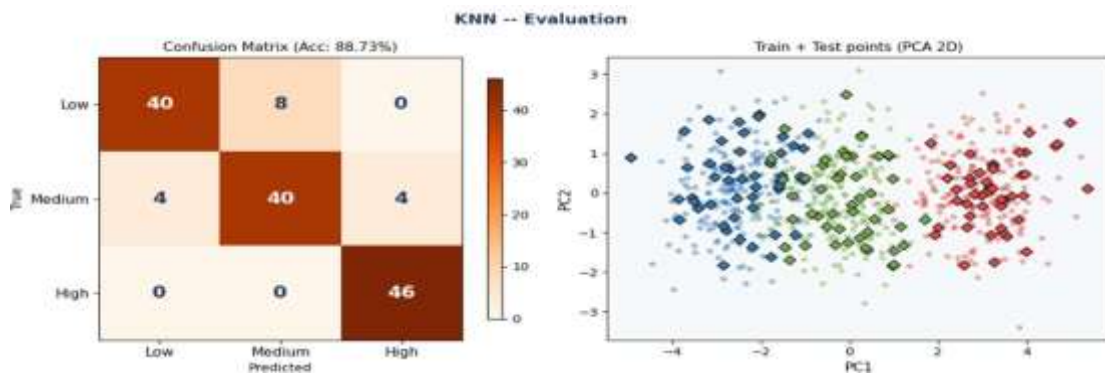
LDA determines linear combinations of features that maximize the ratio of between-class variance to within-class variance (Fisher's criterion). For three classes and 18 features, precisely two discriminant functions (LD1, LD2) are obtained. Solver and shrinkage were optimized via grid search. Result: 97.89% test accuracy; FA_Asymmetry drives LD1, proving frontal alpha asymmetry as the critical neural predictor.



Feature Approaches

Two category of features

Feature	Type	EEG band / unit	ANOVA F-stat	Anxiety direction
React_Time	Behavioural	seconds	~754	Higher = more anxious
Social_Avoid	Behavioural	count	~744	Higher = more anxious
Traj_Deviat	Behavioural	metres	~639	Higher = more anxious
Recall_Score	Behavioural	proportion	~605	Lower = more anxious
Error_Rate	Behavioural	ratio	~605	Higher = more anxious
Gaze_Social	Behavioural	seconds	~574	Lower = more anxious
Nav_Time_s	Behavioural	seconds	~420	Higher = more anxious
F4_Alpha	EEG	8-13 Hz (F4)	~463	Lower = more anxious
Fz_Theta	EEG	4-8 Hz (Fz)	~428	Higher = more anxious
Pz_Alpha	EEG	8-13 Hz (Pz)	~389	Lower = more anxious
FA_Asymmetry	EEG	F4-F3 alpha	~352	More negative = more anxious
Cz_Gamma	EEG	30-45 Hz (Cz)	~320	Higher = more anxious



V. DISCUSSIONS AND IMPLICATIONS

The combination of AR VR AND machine learning technology is a big step forward in finding new ways to treat disorders. The standard methods are pretty limited because they rely on set protocols, clinician observations and don't allow for personalization. Smart missive platforms on the other hand make it possible for intervention that is adaptive, data driven, and very interesting [11] [27].

5.1 Clinical Uses

The primary significance of AR/VR-based therapies is their capacity to offer safe and regulated exposure to the environment or fear triggers.

Exposure is one of the finest ways to cure anxiety disorders. Immersion technology helps replicate unpleasant scenarios that could be costly or even hazardous for patients in the real world [13] [15]. Both the levels of difficulty and the rate of improvement can be controlled. Furthermore, ML-enabled devices can adjust the degree of treatment based on patients' physiological and behavioral responses. For instance, if an app detects excessive anxiety, it might help the patient relax by reducing stressors or offering calming activities [11], [32].

5.2 Accessibility and Scalability

Another major implication of immersive digital therapy lies in its accessibility. Traditional therapy typically involves physically attending sessions, having therapists, and traveling back and forth, which may not be practical for people residing in rural locations, far-flung settlements, or areas where there is an inadequate supply of clinicians [29]. Virtual reality and augmented reality therapy systems could potentially be accessed by remote patients via personal devices such as head-mounted displays or smartphones. Once implemented, these technologies have the potential to serve many users at once with lower incremental costs than individual therapy sessions. This would prove useful especially for nations with rising mental health issues but insufficient facilities.

5.3 Ethical and Privacy Concerns

Although the approach provides many significant benefits, the adoption of immersive therapy systems

brings about certain ethical concerns. Personal information, such as emotions, movements, voice data, biometrics, and mental state indicators, may get collected by augmented and virtual reality systems; thus, without proper security measures in place, the above data could easily be misused.

To address this challenge, developers of VR/AR solutions and healthcare organizations need to make sure that there is:

Data encryption during transfer and storage

Informed consent from patients

Transparency in AI algorithms' decision-making

Adherence to medical privacy laws

Human monitoring of any automated procedures

Another issue relates to potential dependency on technology. Even though the proposed solution is an important tool, it cannot completely replace human practitioners in providing adequate psychological care.

5.4 User Experience and Acceptance

User acceptance and usability play a key role in any digital therapy system. Patients who have uncomfortable experiences with these applications tend to discontinue their treatments. Realism, interaction quality, wearability, and presence all contribute significantly to successful therapy [14], [18]. Nevertheless, some issues, including cybersickness, eyestrain, the weight of headsets, technical issues, and user interfaces that require additional learning time can be considered barriers. Therefore, it is vital to focus on user-centered design, creating lightweight solutions that are easy to use, compatible with a broad range of age groups, and adjustable according to personal tolerance.

5.5 Societal Implications

Incorporating AR and VR technology into mental health therapy systems might help decrease stigma by providing people with the opportunity to receive professional help from the convenience of their homes. Early intervention is likely, as those who do not wish to undergo treatment at the clinic might prefer using technological solutions. Additionally, educational organizations, work environments, and rehab facilities might benefit from immersive wellness courses.

VI. LIMITATIONS AND FUTURE SCOPE

6.1 Limitations

High Implementation Cost

One of the biggest challenges faced here is financially cause all these devices are high in cost and require more financial need to work on for hospitals, clinics, schools. Cost can be reduced but only if there are big companies willing to reduce profitable market. It especially applies to countries with developing economies that have low budgets allocated to mental disorders.

Technical Complexity

The creation of an immersive therapy platform for clinical purposes requires multidisciplinary skills and experience from professionals in various fields of knowledge including psychology, programming, human-computer interaction, biometrics, and AI modeling. A lot of medical facilities might not have specialists capable of working with such complex technology.

Cybersickness and Physical Discomfort

The problem associated with VR applications is physical discomfort. Cybersickness refers to symptoms like dizziness, vomiting, headaches, eye strain, exhaustion, and dizziness caused by extended usage of virtual reality goggles. They can make patients unwilling to proceed with further therapy sessions.

Poor Data Quality for Machine Learning Applications

As machine learning depends largely on quality data, datasets from research that includes a small number of observations, a short duration of the study, or participation of non-diverse samples might negatively affect the generalization capabilities of models

Bias and Ethical Considerations

If the training dataset is uneven in terms of factors such as age, sex, culture, or severity of the condition, then AI applications can produce bias in the results. For mental health conditions, wrong prediction will mean improper treatment intensity or unnecessary delays in interventions. Thus, rigorous validation and clinician guidance become necessary.

Absence of Consistent Clinical Protocols

There is no single protocol that all the researchers follow when using AR/VR technologies for therapy sessions. Divergence in types of devices used, duration of exposures, contents of therapeutic exercises, and evaluation criteria makes cross-study comparisons almost impossible.

6.2 Future Scope

Personalized Therapies via AI

Systems in the future will be designed to make use of AI technologies to constantly gather information about patients' behavior and fine-tune therapies to achieve better results. An intelligent platform will be able to regulate difficulty, session time, emotional encouragement, and exposure level in accordance with patients' reactions.

Improvement through Reinforcement Learning

ML techniques, for example reinforcement learning, are also likely to contribute to more personalized therapy since they help to figure out the most effective methods of intervention in case of each individual. This may result in the creation of self-evolving ecosystems of therapies.

Integration of Wearable Biosensors

The future therapy systems are going to incorporate different biosensors, including smartwatches, EEG bands, heartrate meters, skin conductance measures, eye tracking devices, etc., that will allow collecting information about patients' emotions, reactions, stress, and recovery process.

Advances in Cheap and Mobile Technologies

The increase in availability of VR and AR gadgets powered by smartphones is another factor that may considerably enhance the accessibility of therapies.

Telemedicine and Remote Monitoring

The combination of immersive therapy with telemedicine applications can give therapists the capability to remotely monitor their patients and intervene as required. This will be very helpful for users who live in rural areas or locations where there is a scarcity of mental health practitioners.

Clinical Studies on a Large Scale

Future studies should focus on multicenter randomized clinical trials that involve diverse subjects with follow-up periods.

VII. CONCLUSION

Nevertheless, Anxiety Disorders remain a global health concern and adversely affect emotional health, social relations, productivity, and general quality of life [1], [29]. Cognitive Behavioral therapy and medication are effective treatments, but they are not commonly utilized due to accessibility issue, high cost, potential side effects, not many health care professionals [29],[30]. The review also talked about how machine learning can turn strict treatments method into smart and adaptable ones. Still there are some limits that make it hard to use it more widely. Cost of implementation and biased factors are hindering widespread implementation [18], [27].

In conclusion, immersive health care has a lot of promise. Improved hardware design, improved wearables for biofeedback measurement, telemedicine and adaptive intelligent systems will make augmented and virtual reality techniques more useful and easier to work on.

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