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Effect of Virtual Reality and Artificial Intelligence on Anxiety and Behavior Among Individuals with Mental Disabilities in a Dental Setting

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ABSTRACT

Over one million individuals suffer from mental disabilities in Saudi Arabia. These individuals are unable to express their dental treatment needs. This study focuses on assessing the impact of interventions based on virtual reality (VR) and artificial intelligence (AI) on the anxiety levels and behavioral responses of individuals with mental disabilities when undergoing dental treatments. Our findings indicate that VR and AI interventions have great potential in reducing anxiety and behavioral responses of individuals with mental disabilities. The reduction in anxiety levels was determined using a galvanic skin response sensor, whereas the improvement in behavior was evaluated using the Venham and Frankl behavior rating scales. Descriptive statistics were used to calculate the means, standard deviations, and ranges of the scores on various scales. The mean scores of pretreatment and posttreatment were analyzed. Our results from the above-mentioned tests revealed lowered anxiety and positive behavior when VR and AI interventions were used in dental care settings. In conclusion, our research indicates that distraction using VR and AI interventions is an effective method for lowering anxiety and improving behavior among individuals with mental disabilities during dental treatments. Moreover, a positive correlation between anxiety and behavior was observed.

KEYWORDS

behavioral responses, dental setting, mental disability, Saudi Arabia, virtual reality, artificial intelligence, anxiety

INTRODUCTION

The World Health Organization describes a mental disorder as a clinically significant impairment of a person's cognition, emotional regulation, or behavior. It is typically linked to distress or functional impairment in key areas. According to estimates, up to 500 million people require special care because of one or more disabilities brought on by physical, mental, or sensory problems (Holder et al., 2009).

The number of people coping with mental health issues continues to be high despite improvements in understanding the causes of mental diseases and improved access to professionals for treatment and therapy. In a systematic review and analysis by Steel et al. (2014), the lifetime prevalence of a common mental condition (anxiety disorder, mood disorder, major depressive disorder, or substance-use disorders) was estimated to be 29.2% (Steel et al., 2014). Furthermore, there is substantial evidence indicating that, compared to the general population, those with intellectual disabilities have proportionally more untreated or inadequately treated tooth decay. According to the 2001 National Survey of Children with Special Health Care Needs, the highest unmet need for this demographic was dental care (Lunka, 2020). Individuals with special health care needs are associated with psychological, behavioral, and physical complications, and thus may already have complex medical backgrounds that prevent them from receiving the required dental care (Adenubi and Martinez, 1997; Al Agili et al., 2004; Murshid, 2005; Al-hussyeen et al., 2006).

The field of mental health treatment is undergoing a technological revolution. Artificial intelligence (AI), if employed properly, can generate scenarios that are practicably difficult to replicate in real life but can be therapeutically beneficial. This can reduce inconsistent therapy delivery by allowing

for repeated, readily available, and higher treatment inputs (Freeman et al., 2017). Fully or partially virtual environments can now be created using various methods. Four types of reality have been identified in the literature: the real world, augmented reality (where computer-generated data are combined with real-world imagery), augmented virtuality (where real-world information is combined with a computer-generated world), and virtual reality (VR; where the world has been created entirely by a computer) (Ambroży and Serafin, 2016).

The ability of VR to "transport" consumers into a virtual environment and give them a sense of "presence" is its most distinctive advantage. Immersion and interaction are the two primary aspects of VR. Immersion denotes being present in a virtual environment, whereas interactivity refers to the operator making changes. The immersive nature of VR may aid in managing anxiety in children, as distraction is one of the most successful methods for managing behavior and lowering fear associated with dental treatments. Several dental studies have demonstrated that distraction techniques such as the use of VR may effectively aid in diverting children's attention from anxiety-provoking stimuli, resulting in a calming experience for the child (Cassidy et al., 2002; Hoffman et al., 2011). Fakhruddin showed a greater reduction in anxiety (based on heart rate) when children with autism spectrum disorder or attention-deficit/hyperactivity disorder watched cartoons on VR glasses compared with projections on the ceiling while performing sealants or restorations (Fakhruddin and El Batawi, 2017). Another study showed that anxiety and behavior improved when watching cartoons using video goggles versus handheld EVS (Isong et al., 2014).

Purpose of the study

This study aims to examine whether watching an immersive video using VR glasses along with an AI intervention reduces anxiety and improves behavioral responses in individuals with moderate to severe mental disabilities, including cerebral palsy and Down's syndrome.

It was hypothesized that watching a VR simulation will reduce anxiety by familiarizing the individual with the environment, thereby making minor procedures such as exams, dental prophylaxis, and radiographs more convenient for both dentists/dental hygienists and patients. Positive results for these interventions may suggest that this concept and technology can be used in other medical/social settings to improve the quality of life of individuals with disabilities.

MATERIALS AND METHODS

Study design

This cross-sectional study was conducted between December 2022 and March 2023 among 90 Saudi female residents in a female rehabilitation center in Diriyah. Informed consent was obtained from the caregivers of the participants in the waiting room prior to study initiation. Ethical approval for this study was obtained from the Institutional Review Board, King Saud University (IRB Research Project No-E-22-7366). The screening phase inclusion criteria were being at least 6 years old and having a known diagnosis of intellectual disability at any level and/or severity. The exclusion criteria were (i) blindness, as it would be difficult to engage with study materials, and/or (ii) residents with a history of epilepsy to avoid the risk of provoking epileptic seizures.

Sampling

After obtaining consent, a research assistant collected demographic data from the medical records of the individuals with mental disabilities. The baseline anxiety levels were also assessed. For the participants of this study, the interventions were started after baseline data were collected. All participants were recruited according to the inclusion and exclusion criteria.

Of the 127 individuals with mental disabilities who were examined, 9 refused to wear the VR distraction device, 4 were unable to participate due to deafness, 5 were blind, and 48 had a history of epilepsy and were unable to undergo dental treatment. Eleven individuals were bedridden because of severe mental disabilities. Permission and consent were obtained from the remaining 50 individuals with mental disabilities, who were then scheduled to undergo dental examinations with VR intervention. However, the anxiety scores using Galvanic Skin Response (GSR) was recorded for 40 patients due to the noncompliance of 10 individuals to wear the GSR device. Their dental treatments were limited to a period of 20-25 min and were rated using the anxiety and behavior scales.

Intervention

The psychological aspect of the study focused on assessing the impact of the VR and AI interventions on the participants' anxiety levels and behavioral responses. Anxiety is a common psychological condition that can significantly affect individuals with intellectual disabilities, potentially leading to increased stress and reduced well-being. Therefore, understanding and addressing anxiety in this population is crucial for promoting their overall psychological health and quality of life.

In this study, two interventions based on VR and AI were conducted to investigate their effectiveness in reducing anxiety levels among female residents with intellectual disabilities. VR provides an immersive and interactive environment that can assist individuals with anxiety in practicing relaxation techniques, engaging in calming experiences, and potentially reducing anxiety symptoms.

The VR intervention in this study creates a simulated natural environment with aquatic ecosystems, including a river and wetlands, to provide a soothing and relaxing experience for the participants. The VR intervention was delivered using an Oculus Quest 2 VR headset and software application specifically designed for the best relaxation experience. Cartoon characters designed by Wellnessvio-VR, a Saudi Arabian

company, were also used as they were considered suitable for this population. The interactive environment followed a customized design style.

The AI intervention consisted of an AI-powered environment linked to GSR, which measures emotional arousal. The integration of AI and GSR allows for an immediate shift in the environment and sounds to a more calming environment once the patient reaches the set threshold or when there is a sudden spike in the GSR real-time reading. The anxiety score measured using GSR starts at 0 and is highly individualized; thus, there is no "normal" baseline anxiety score. The scores were used only as a reference point for comparison during or after the interventions. Furthermore, GSR was used to assess the effectiveness of the interventions by assessing anxiety levels at different stages, including preintervention, during intervention, and postintervention, to provide a comprehensive understanding of the impact of the interventions over time.

Outcome measures

After obtaining demographic data and applying the study criteria, the recruited participants underwent nonsurgical dental procedures and were subjected to different tests with and without VR to assess their anxiety, behavior, and level of cooperation. VR and GSR were connected to a laptop to enable the practitioner to view both the GSR readings and the VR real-time experience (Fig. 1). Participants received 15-30 minutes of the intervention.

GSR anxiety scores

A GSR device was used to assess the effectiveness of the interventions by assessing anxiety levels at different stages, including preintervention, during intervention, and postintervention, to provide a comprehensive understanding of the impact of the interventions over time (Fig. 2).

Figure 1: Patients being subjected to nonsurgical dental procedures with VR intervention. Abbreviation: VR, virtual reality.

Figure 2: Oculus Quest 2 VR headset and GSR connected to the laptop. Abbreviations: GSR, galvanic skin response; VR, virtual reality.

GSR was measured in the following three stages:

- Pretreatment: This measure was captured 2 min before starting the treatment while wearing the VR set.
- During the treatment: This measure was collected at the midpoint of the intervention period while wearing the VR set.
- Posttreatment: This measure was collected after the intervention period while wearing the VR set.

Frankl behavior rating scale

A self-administered rating scale was used to assess behaviors or levels of cooperation of individuals with mental disabilities in a dental setting.

- PreFrankl score: This variable represents the behavior and cooperation of individuals with mental disabilities during the previous as-usual treatment session, as assessed by a trained practitioner using the Frankl Behavior Rating Scale. This scale rates behavior on a 4-point scale ranging from 1 (definitely negative) to 4 (definitely positive).
- PostFrankl score: This variable represents the behavior and cooperation of individuals with mental disabilities during the intervention session, as assessed by a trained practitioner using the Frankl Behavior Rating Scale.

Venham anxiety and behavior scale

The Venham Anxiety and Behavior Scale was used to assess dental anxiety in individuals with mental disabilities. It is composed of a series of eight picture sets, showing a diagrammatic representation of two images depicting different behaviors: one showing highly anxious or upset behavior and the other not. Each image that resembled the feelings and behaviors of the participant was marked by a psychologist on each of the eight picture sets, and the scores were compared. The anxiety score for any child ranged from a

minimum score of 0 (not anxious at all) to a maximum score of 8 (extremely anxious).

- Venham anxiety and behavior without VR: This variable represents the anxiety and behavior assessment of individuals with mental disabilities during treatment without VR.
- Venham anxiety and behavior with VR: This variable represents the anxiety and behavior assessment of individuals with mental disabilities during treatment with VR.

Data collection and statistical analysis

Data were collected from individuals with mental disabilities participating in the study, and the results were tabulated and subjected to statistical analysis. IBM SPSS software version 20.0 for Windows was used for data analysis. Descriptive statistics were used to calculate the means, standard deviations, and ranges of the scores on various scales. The level of significance was set at $P \leq 0.05$.

RESULTS

Anxiety rating

Anxiety scores were recorded using GSR, and the data were plotted on a graph for further analysis. The results showed an evident decrease in anxiety score peaks as the VR intervention progressed. The most important observation was that the GSR scores during treatment with VR showed the lowest peaks, suggesting that the lowest anxiety experienced by these individuals was during treatment along with VR and AI interventions (Fig. 1). The mean GSR score reduced from 1.794 (pretreatment) to 1.154 (during treatment). The mean posttreatment GSR score showed a significant reduction to 0.786, which was lower than both the pretreatment and during-treatment mean scores. The obtained *P* values were statistically significant ($P < 0.05$) (Table 1).

Venham anxiety and behavior scale

The number of individuals exhibiting higher scores that depict higher anxiety and negative behaviors reduced when VR-based distraction was used. The number of individuals with a score of 2 or higher decreased. All the participants exhibited positive scores of either 0 or 1 using VR.

Upon further analysis, the mean Venham anxiety scores showed a significant reduction with VR from 2.926 without VR to 0.170 with VR. A comparison between the behavioral rating scores with and without VR revealed a statistical significance ($P < 0.0001$) (Table 2).

Frankl behavior rating scale

The number of individuals with mental disabilities exhibiting a score of 1 or 2 (1 = definitely negative, 2 = negative) diminished from 25 individuals with a score of 2 without VR intervention to 0 individuals with a score of 2 with VR intervention. Those exhibiting a score of 4 (definitively positive) increased from 0 for individuals treated without the VR intervention to 19 for individuals treated with the VR intervention.

Upon further analysis, the mean Frankl behavior scores showed a significant increase with VR—from 2.390 without VR to 3.141 with VR—suggesting improvement in this case, as higher scores indicate positive behavior. A comparison between the behavior rating scores with and without VR revealed a statistically significant difference (Table 3, Fig. 3).

Table 2: Mean and standard deviation scores of Venham Anxiety & Behavior Rating.

Venham score	Number of mentally disabled individuals		*P* value
	Without VR	With VR	
0	0	34	
1	0	7	
2	3	0	<0.00001
3	38	0	
4	0	0	
5	9	9	
Total	50	50	

P value ≤0.05 is significant, and *P* value >0.05 is not significant.
Abbreviation: VR, virtual reality.

Table 3: Calculations and comparison of Frankl Scores.

Behavior rating Frankl scores	Number of individuals with mental disabilities		*P* value*
	Without VR	With VR	
1	9	9	
2	25	0	
3	16	22	<0.00001
4	0	19	
Total	50	50	

**P* value ≤0.05 is significant, and *P* value >0.05 is not significant.
Abbreviation: VR, virtual reality.

Table 1: Mean and standard deviation of GSR scores of all individuals with mental disabilities: Pretreatment and posttreatment.

	Pretreatment	During treatment	Posttreatment
Mean (μ)	1.79475	1.15475	0.78625
Standard deviation (s)	1.7219392955328	1.0899357492531	0.85028432744583
P* value	0.02671		0.000778

**P* value ≤0.05 is significant, and *P* value >0.05 is not significant.
Abbreviation: GSR, galvanic skin response.

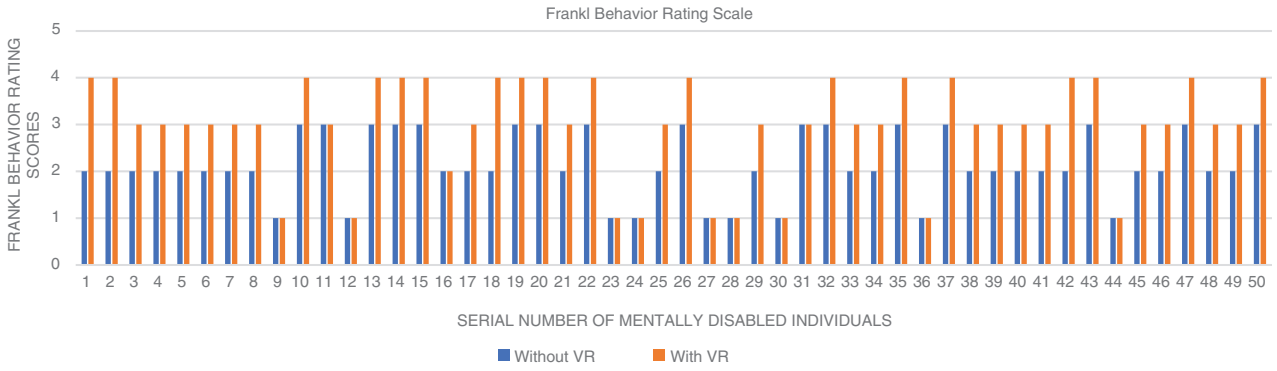

Figure 3: Frankl scores comparison chart: With and without VR intervention. Abbreviation: VR, virtual reality.

DISCUSSION

Individuals with mental impairments have special health care needs and are also more prone to dental anxiety; therefore, they tend to exhibit poor oral health. Most of these individuals cannot verbalize their concerns and exhibit a fear of dental treatment. Consequently, when individuals with mental disabilities report to a dental clinic, the existing routine management protocols are unsuitable because of several barriers. Hence, new techniques, such as AI- and VR-based interventions, are required to reduce anxiety in this population.

Based on previous studies that have demonstrated its effectiveness, VR and AI are emerging technologies with great potential to be used in dental and medical procedures as a tool for distraction and behavior management (Wismeijer and Vingerhoets, 2005; Aminabadi et al., 2012). Similarly, literature review indicated that most studies employing VR-based distraction resulted in reduced stress levels (Prabhakar et al., 2007; Patterson et al., 2010). These advantages may be attributed to the more immersive nature of VR because of occlusive headsets, which project images directly in front of the user's eyes while blocking real-world (visual, auditory, or both) stimuli. The attention of individuals with mental disabilities is drawn to what is happening in the virtual world rather than in their surroundings.

Although the effectiveness of VR and AI interventions in reducing anxiety has shown promise in various populations, including individuals with anxiety disorders, specific research on female residents with intellectual disabilities in rehabilitation centers remains limited. Therefore, our study aimed to contribute to the existing literature by exploring the effectiveness of these interventions in reducing anxiety and improving the psychological well-being of this specific population.

The methodology followed in this study was carefully constructed with counsel from an experienced clinical psychologist, dental hygienists, and a general practitioner doctor, who decided to perform routine noninvasive dental treatment within the confines of the houses of those with intellectual disabilities. Given that many individuals with mental disabilities in this study had no prior exposure to dental teams, this choice was made to help decrease anxiety levels in individuals with mental disabilities and encourage better collaboration during dental appointments. The GSR anxiety sensor used in our study employs two electrodes placed on the fingers to operate as two terminals of a single resistance and provides readings by measuring the voltage. These voltage readings determined the anxiety scores, which could be as low as 0.01 and do not have a defined upper limit. Our results revealed that watching immersive videos led to a significant reduction in the reported anxiety scores (Table 1, Fig. 4). This is line with the findings of various studies conducted in children without mental disabilities, where the use of VR-based distraction during dental and medical treatments led to a reduction in participants' reported pain, anxiety, and discomfort (Seyrek et al., 1984; Charitos et al., 2000).

In this study, along with reduction in anxiety, a substantial improvement in behavior was also observed in individuals with mental disabilities (Tables 2 and 3, Fig. 2). The Venham Behavior Rating Scale, with scores ranging from 0 to 5 (positive to negative), showed significant improvement. The number of individuals with mental disabilities with positive scores of 0 or 1 increased from 0, without VR- and AI-based interventions, to 41, with VR- and AI-based interventions. Similar results were obtained using the Frankl Behavior Rating Scale, which has scores ranging from 1 to 4 (negative to positive). These results also showed a high positive correlation between anxiety levels and the corresponding improvements in the behaviors of individuals with mental disabilities. These findings concur with those of previous studies in which patients with high anxiety levels had more behavioral responses (Charitos et al., 2000; Suresh and George, 2019). This correlation is highly significant to our study as it would enable individuals with mental disabilities to undergo routine dental treatments in dental care settings without overtly exhausting the caregivers and the dental team owing to constant disruption and violent outbursts in their behavior. Careful application of this technique may also increase the willingness of dental practitioners to treat individuals with mental disorders. These findings provide further evidence that anxiety impedes patients' ability to cope with dental treatment procedures and increases emotions toward health care. The overall findings support the effectiveness of VR-based interventions in minimizing anxiety levels and negative emotions in individuals with mental disabilities.

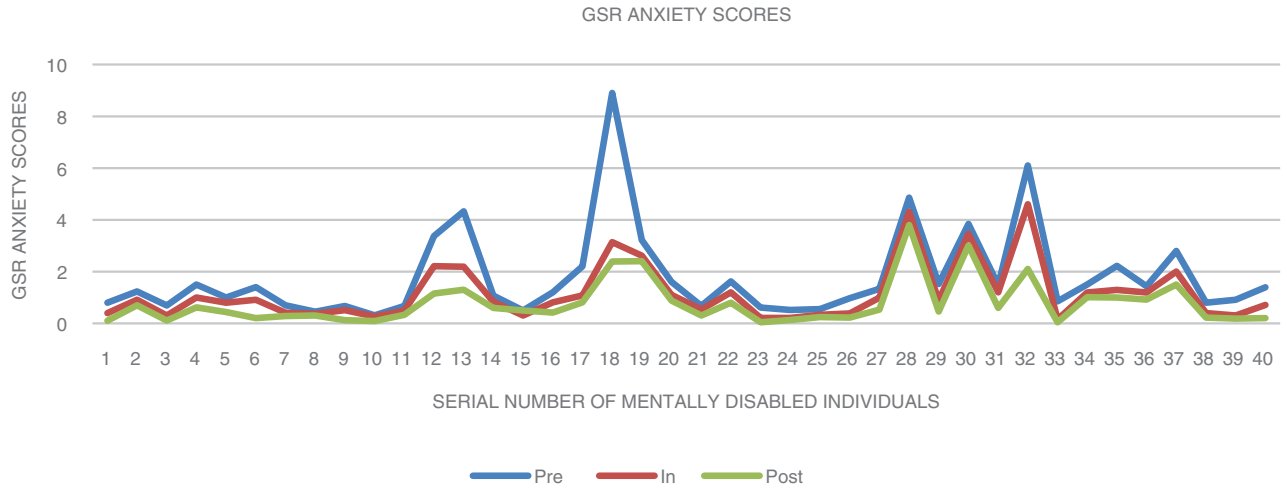

Figure 4: GSR with the VR intervention: Pretreatment, during treatment, and posttreatment. Abbreviations: GSR, galvanic skin response; VR, virtual reality.

The current study's sample size is a limitation. A bigger sample size may reveal more group differences. The results of this study can be generalizable to patients with mental disability.

CONCLUSIONS

A significant decrease in anxiety and improvement in behavior were observed in people with mental disabilities during routine, noninvasive dental treatment procedures using VR-based distraction. VR-based distraction can be used as a successful behavioral management method during routine dental treatment. However, individuals with severe mental disabilities and behavioral problems may require general anesthesia to facilitate compliance.

The findings of this study generate new knowledge and evidence about VR interventions involving customized videos. We believe that VR and AI interventions can be applied to all adults, regardless of their disability or the clinical setting. Given the importance of play in the psychological health of individuals with mental disabilities, it is recommended that the female rehabilitation center authorities recognize this importance by providing more resources and establishing more VR- and AI-based technological facilities for such individuals when they are in a dental clinic. Further research is required to explore the effectiveness and applicability of VR-based distraction in this population when performing more complex medical and dental procedures.

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AUTHOR CONTRIBUTIONS

The authors contributed equally to all parts of this paper.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest in association with the present study.

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DATA AVAILABILITY

The relevant data are contained within the article.

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