



Reducing Anxiety in Pediatric Circumcision Using an Affective-Based Virtual Reality

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Abstract

Anxiety is a common emotional response among children undergoing invasive medical procedures such as circumcision, which can compromise procedural comfort and increase resistance. This study aimed to evaluate the effectiveness of a space adventure-themed Virtual Reality (VR) application as a distraction medium to reduce anxiety in boys during circumcision procedures. It involved 26 children aged 10–14 who participated in this study. Anxiety levels were measured using the State-Trait Anxiety Inventory (STAI-T) instrument before and after the intervention. The application was designed using an Affective Virtual Reality methodology, which integrates emotional elements and immersive experiences into a virtual environment to create a relaxed and enjoyable atmosphere. VR was used during the procedure to distract children from painful and fearful stimuli. The results showed decreased anxiety levels after the intervention, indicating that VR technology is effective as a non-pharmacological distraction strategy in clinical contexts. These findings contribute to the use of immersive technology as an innovative approach to supporting children's psychological comfort during medical procedures and open opportunities for developing similar interventions in other pediatric medical contexts.

Introduction

Circumcision is a surgical procedure involving the partial or complete removal of the penile foreskin, typically performed by a doctor or trained medical personnel (Kalyenci *et al.*, 2025). Circumcision is frequently performed for non-medical reasons such as cultural or religious practices. From a medical perspective, it has been associated with a reduced risk of certain conditions, including balanitis and urinary tract infections (Farley *et al.*, 2020; Matoga, Hosseinipour, Jewett, Hoffman, & Chasela, 2021; Wahyudi, Raharja, Situmorang, & Rodjani, 2023). Evidence from the World Health Organization indicates that male circumcision reduces the risk of heterosexually acquired HIV infection in men, particularly in high-prevalence settings such as parts of sub-Saharan Africa (Loevinsohn *et al.*, 2021; Pintye & Baeten, 2017). Circumcision may be

performed in neonates, infants, adolescents, and adults by physicians or other trained healthcare professionals within appropriate clinical settings (Shabanzadeh *et al.*, 2021). Despite documented health benefits, some individuals perceive circumcision as providing little or no physiological advantage. Such perceptions often stem from limited awareness of clinical indications, cultural or religious beliefs, fear or anxiety about the procedure, and the propagation of misinformation. In certain cultural or religious contexts, circumcision is normative; however, some recipients or caregivers may undergo the procedure without fully understanding its rationale or may feel pressured to consent. In Southeast Asia, circumcision remains common among children and adolescent males and is largely motivated by cultural and religious factors (Didişen & Karakul, 2021; Kurniawan, Daryanto,

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Nurhadi, & Kustono, 2024). In Indonesia, circumcision is commonly performed on boys from approximately eight years of age through adolescence (Arnett, 2012). Despite its widespread practice, many children continue to experience fear and anxiety in relation to the procedure (Lismayanti *et al.*, 2021).

Anxiety and pain may arise in relation to the use of sedatives and other medications, potentially leading to adverse side effects and delayed recovery (Bailey, 2021; Conway *et al.*, 2016). Non-pharmacological interventions, such as distraction techniques, can help reduce pain, anxiety, and fear in children during the perioperative period of circumcision (Wang *et al.*, 2024). Various distraction methods, including watching videos, storytelling, and playing board games, have been employed to reduce anxiety in children during surgical procedures (Wu *et al.*, 2022). The primary strategy for managing distress in children is to divert their attention from unpleasant stimuli, a process that can produce a positive analgesic effect (Lambert *et al.*, 2020). Emerging technologies, such as virtual reality (VR), have been effectively utilized as innovative non-pharmacological distraction techniques (Buyuk *et al.*, 2021; Wu *et al.*, 2022).

VR has been applied in various medical contexts and has proven effective in reducing patient anxiety before procedures (Ganry *et al.*, 2018; Maurice-Szamburski, 2018) or during medical operations (Sikka *et al.*, 2019). From the patients' point of view, it helps them distract their brains from experiencing pain through involvement in certain activities that require cognitive functioning. VR interventions typically employ specialized headsets or goggles that limit interaction with the real environment. Through these devices, patients are immersed in a pre-recorded virtual environment that visually and aurally isolates them from real-world stimuli (Ryu *et al.*, 2019). However, systematic studies on VR content development using an emotion-based design approach remain limited, particularly in the context of pediatric circumcision. To maximize its distraction potential and address the emotional needs of children, the VR intervention in this study was developed using the Affective Virtual Reality (AVR)

design methodology proposed by Dozio *et al.* (2022). This approach emphasizes the creation of affective experiences by integrating visual, narrative, and pacing elements strategically designed to elicit positive emotional states such as relaxation and engagement

A comparable methodological application in the digital health domain was reported in a study evaluating "emotional everyday scenarios" within a VR-based health application (Wunsch *et al.*, 2024). However, this approach has not yet been clinically tested in pediatric patients undergoing medical procedures. An integrative review of affective visualization in VR has nonetheless highlighted the potential of virtual visual biofeedback in affective therapy and anxiety management (Pinilla *et al.*, 2021). The relationship between affective design and the clinical outcomes of VR interventions remains underexplored. Most prior studies have concentrated on the use of VR as a distraction tool, without explicitly describing the emotional design process underpinning content development. Consequently, there is a need for non-pharmacological strategies that can engage children in a fun and immersive manner, effectively diverting attention from medical procedures and reducing anxiety responses. In light of this gap, the present study addresses the following research question: How can a virtual environment developed using virtual reality technology and guided by the Affective Virtual Reality (AVR) approach reduce anxiety in children undergoing circumcision procedures?

This study aims to develop a virtual environment model using virtual reality (VR) technology designed according to affective design principles to distract children and foster a positive procedural experience during circumcision. The contributions of this work are twofold. First, it involves the development of a prototype 3D space adventure-themed environment, created in accordance with the Affective Virtual Reality (AVR) framework, to mitigate fear, pain, and anxiety in pediatric patients. Second, it includes an evaluation of the intervention's effectiveness in reducing anxiety levels, as measured by the State-Trait Anxiety Inventory (STAI; Spielberger, 1972), with statistically significant reductions

demonstrated through paired t-test analysis.

Method

The development of the virtual environment as a distraction medium during circumcision procedures employed the Affective Virtual Reality (AVR) design methodology (Dozio *et al.*, 2022). The AVR methodology consists of three main stages: (1) analyzing emotions in real-world contexts, (2) conceiving emotions within virtual environments (VEs), and (3) assessing emotional responses. This approach was selected to ensure that the VR application would establish a strong emotional connection with its users, as it was intended to divert attention from fear and discomfort during the circumcision procedure. Figure 1 provides an overview of how the AVR methodology was applied to design a virtual environment tailored to the needs of participants in this study.

In the first stage, understanding emotions in the real world, system developers identify the intended purpose of the virtual environment. In this study, the environment was designed

to divert fear and anxiety, with the target emotional state being pleasant. Accordingly, the virtual environment aimed to create an enjoyable and engaging atmosphere for users during the circumcision procedure. Given that the participants were boys, and considering their general interest in exploration, modern technology, and outer space themes, an outer space adventure setting was selected as an appropriate and enjoyable environment.

The second stage involved creating an active virtual reality experience by defining and integrating specific design elements within the virtual world, including visually appealing components such as space stations, guide robots, recognizable planets, stars, flying spacecraft, and other outer space objects, all constructed in 3D. Background audio was incorporated to promote relaxation and convey a calming sensation, and a narrative element was added to enhance user engagement and enjoyment. The final stage comprised the assessment and

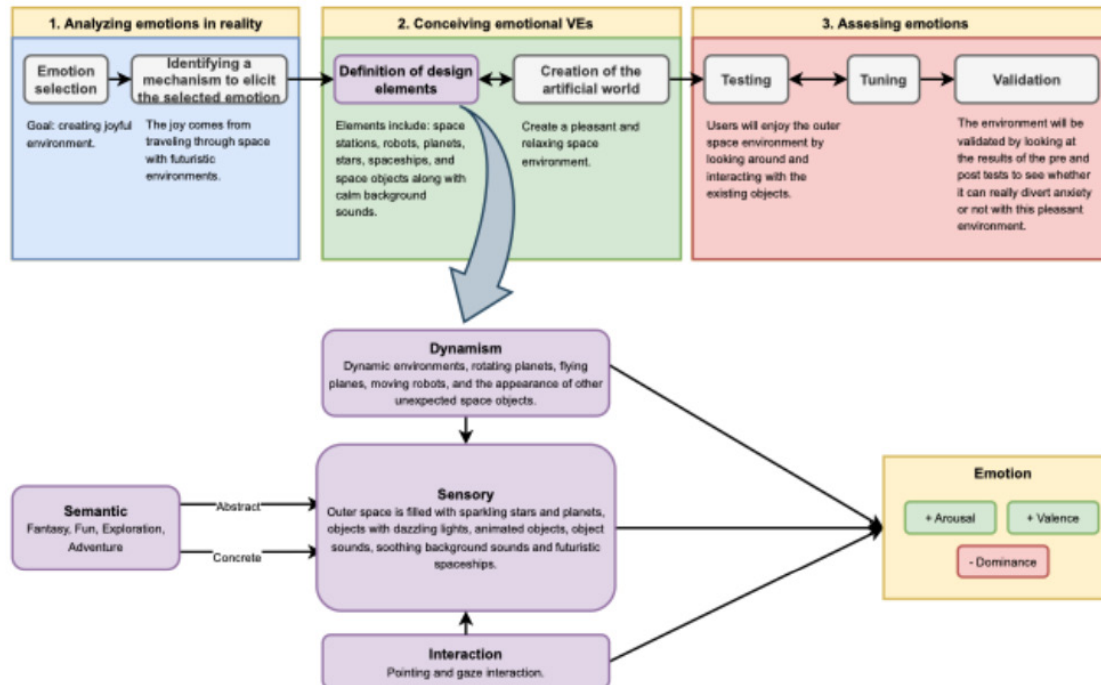


FIGURE 1. The Proposed AVR Methodology with Design Elements Definition and Their Effects on the Emotional Dimension

validation of the emotional impact of the virtual world, beginning with pilot testing on healthy children to ensure functionality and identify potential technical issues. Following confirmation of system stability, the application was implemented with circumcision patients, accompanied by a medical check to ensure user safety. To verify whether the virtual space environment effectively elicited a pleasant emotional state, anxiety levels were measured before and after VR exposure using the State Trait Anxiety Inventory (STAI; Spielberger, 1972).

Embedding specific emotions into a system requires analyzing the various aspects that influence emotional responses, namely, semantic elements, sensory elements, dynamic elements, and interactions. Semantic elements serve as the starting point, evolving into sensory elements that can be abstract or concrete. Abstract sensory elements, such as melodies, distinctive shapes, or certain visual components, are not immediately recognizable but may evoke particular emotions, whereas concrete elements, such as planets or aircraft, represent forms resembling the real world. Dynamic elements refer to the movement and interaction between virtual objects and user actions, which may involve sensory experiences like observing virtual characters or hearing ambient sounds. Interaction encompasses the user's engagement with the system, whether performed freely, within certain constraints, or through suggested actions. Similar to the five senses, sensory elements in virtual environments may include visual, auditory, olfactory, and tactile components, each of which plays a direct role in eliciting emotional responses. In this context, emotions are characterized across three dimensions: arousal, valence, and dominance.

Figure 1 also illustrates the proposed design elements and their effects on the emotional dimension. In the semantic element, the user who is undergoing circumcision faces a frightening real-world situation; however, the virtual environment is intentionally designed to be the opposite, presenting an unrelated fantasy world that evokes joy. The concrete form chosen is an outer space environment, reflecting boys' strong interest in technology and space

exploration, while the abstract form includes numerous planets that, although not perfectly resembling the vast emptiness of real outer space, convey a sense of wonder. Dynamism is incorporated through moving objects, such as rotating planets, passing spacecraft, guide robots, and unexpected celestial appearances. The 3D objects are created using Blender 3D and sourced from various free assets, while the overall virtual environment is developed using Unity software.

The chosen interaction mode is passive exploration, in which users are limited to pointing and gazing. This restriction is essential to prevent excessive interactivity that could interfere with the circumcision procedure taking place in the real world. Sensory design integrates semantic, concrete, and dynamic elements to influence the user's psychological state. The sensory stimuli include the experience of a sparkling outer space filled with various moving objects, accompanied by animations and calming background sounds. In the core scene, users lie down while immersing themselves in the beauty of the virtual environment, a setup intended to elicit both arousal and valence responses. Arousal here refers to the psychological and physiological activation of the body, which can foster positive emotions and help divert attention from the ongoing real-world procedure. Valence describes the emotional quality of the experience, ranging from positive to negative feelings. The intended effect is to achieve a balanced state of moderately excited arousal combined with positive valence so that users feel engaged and happy without becoming overly stimulated. By maintaining this balance, the design reduces dominant emotional responses and supports a calm, enjoyable experience through passive interaction.

The developed virtual environment is realized as a virtual reality application called "Space Tour VR", designed for patients undergoing circumcision. As a sequel to the educational game Teeny Boy, which prepares children before the procedure, Space Tour VR runs on the Meta platform using the Meta Quest 3. Its purpose is to serve as an intervention tool, diverting attention during surgery to reduce patient anxiety and fear. When first opened,

Space Tour VR presents a main menu where users can immediately start. The experience begins with the user seated to adapt to the VR device. A virtual robot provides instructions, guiding them to explore the International Space Station using head movements and controller-based hand interactions. The robot then directs the user to a door, which opens to reveal a plane. After viewing it, the user boards the plane and lies down, enjoying outer space scenery with soothing background sounds coinciding with the start of the circumcision procedure.

Result and Discussion

This study employed a quantitative approach using a quasi-experimental one-group pretest-posttest design, characterized by the absence of a control group and measurement of the dependent variable before and after intervention. The dependent variable was assessed twice, in the preoperative and postoperative phases. Ethical clearance was obtained from the Faculty of Medicine, Universitas Negeri Semarang (Approval No. 461/KEPK/FK/KLE/2024). Participants in this study were boys aged 10–14 years undergoing circumcision, who provided informed consent to participate in the intervention. They were recruited from the host institution or clinic performing the circumcision. A total of 26 Indonesian children and adolescents from three different regions were involved in the assessment. The participant demographics were as follows: 3 aged 10, 10 aged 11, 7 aged 12, 5 aged 13, and 1 aged 14.

The research instrument was adapted from the State-Trait Anxiety Inventory (STAI) to assess the anxiety levels of circumcised boys. The STAI comprises two components: the State Anxiety Scale (STAI-S), which measures temporary, situation-specific anxiety, and the Trait Anxiety Scale (STAI-T), which measures a general tendency toward anxiety (Spielberger, 1972). Responses are rated on a scale indicating the intensity or frequency of feelings (e.g., “Almost always” to “Never”). In clinical contexts, the STAI is used to diagnose anxiety disorders or assess anxiety’s impact on emotional well-being, while in educational settings, it helps identify students experiencing situational or chronic anxiety. Its brevity and

clarity make it effective for detecting anxiety and guiding appropriate emotional support.

The STAI-T consists of 20 statements, including 11 negative (anxiety-related) and 9 positive (non-anxiety-related) items. Negative statements are scored on a 4-point Likert scale (1 = never, 2 = sometimes, 3 = often, 4 = always), while positive statements are reverse-scored. Anxiety levels are categorized as follows: normal (20–29), mild (30–39), moderate (40–49), and severe (50–80). To facilitate data collection, the English version of the instrument was translated into Indonesian by a professional translator. The STAI-T demonstrates a sensitivity of 94%, indicating its strong ability to detect anxiety in individuals.

1. Saya merasa tenang/ I feel calm
2. Saya merasa aman/ I feel secure
3. Saya merasa gugup/ I feel tense
4. Saya merasa badan saya tidak nyaman/ I feel strained
5. Saya merasa nyaman/ I feel at ease
6. Saya merasa kesal/ I feel upset
7. Saya sedang mengkhawatirkan kemungkinan tidak beruntung/ I am presently worrying over possible misfortunes
8. Saya merasa lega/ I feel satisfied
9. Saya merasa takut/ I feel frightened
10. Saya merasa tidak nyaman/ I feel uncomfortable
11. Saya merasa percaya diri/ I feel self-confident
12. Saya merasa cemas/ I feel nervous
13. Saya merasa gelisah/ I feel jittery
14. Saya merasa bimbang/ I feel indecisive
15. Saya merasa rileks/ I am relaxed
16. Saya merasa bahagia/ I feel content
17. Saya khawatir/ I am worried
18. Saya merasa bingung/ I feel confused
19. Saya merasa tubuh saya baik-baik saja/ I feel steady
20. Saya merasa senang/ I feel pleasant

The circumcision method was used with a super ring with injection anaesthesia (not with a regular syringe) by healthcare professionals through mass circumcision procedures (more than one patient at a time). The procedure for each participant during circumcision and intervention was as follows:

1. Each participant sits in the waiting room and waits to be called.

2. The health practitioners will check each participant's health, such as blood pressure, anaemia, and oxygen saturation.
3. Participants enter the anaesthesia room on their own and receive anaesthesia by injection.
4. After that, participants wait to enter the circumcision room. While waiting, the officer gives each participant a consent form and STAI pretest questionnaire. The consent form is completed and signed by their parents or guardians.
5. Participants who have completed the pretest can immediately enter the circumcision room.
6. Participants will be lying on the bed using the Meta Quest 3 device. Each participant will be accompanied by a VR application operator and monitored from the operator's smartphone.
7. After the participants settle down and use the Meta Quest device, they will lie down and enjoy the space journey with Space Tour VR. When a patient lies down, it will be circumcised.
8. When finished, the participants will remove the device and wait in the waiting room. While waiting, participants will receive an STAI post-test questionnaire with the identical instrument content as the pretest.

Figure 2a presents the STAI-T score distribution for 26 participants. The maximum possible score is 80, with higher scores indicating greater anxiety. Descriptive statistics (Table 1) show that the mean pre-test anxiety score was 55.12 (SD = 6.32), which decreased to 51.65 (SD = 6.85) after the Virtual Reality intervention. The mean difference of 3.46 points reflects a reduction in anxiety levels following the intervention.

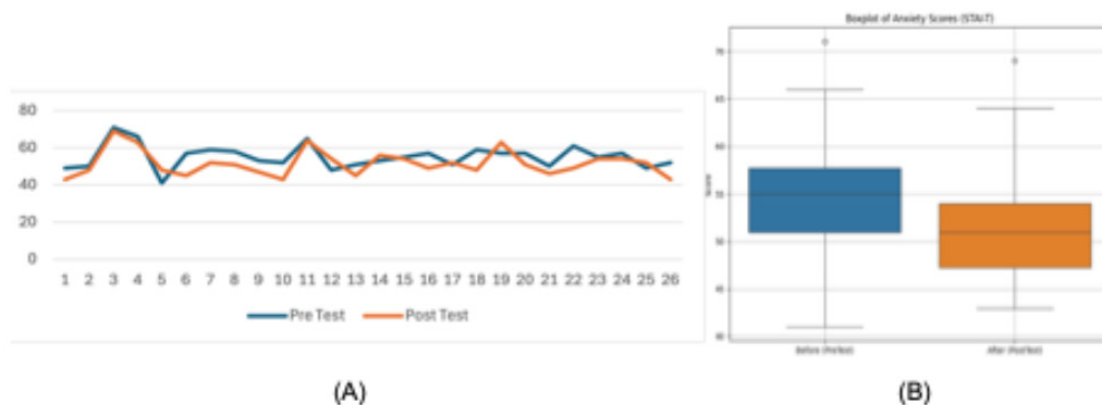


FIGURE 2. Pre- and Post-Test Results of Participants with VR Intervention (A) and Boxplot Result (B)

TABLE 1. Statistical Descriptive Results of Participants

	Pre Test	Post Test	Δ (delta)
Count	26	26	26
Mean	55.1153	51.6538	3.461
Std	6.3202	6.8524	5.4789
Min	41	43	-7
25%	51	47.25	1
50%	55	47.25	3.5
75%	57.75	54	7
Max	71	69	12

TABLE 2. The Summary of the Statistical Test for STAI-T

Test	Statistic Value	p-value	Interpretation
Shapiro-Wilk Pretest	0.9639	0.4760	Normal ($p > 0.05$)
Shapiro-Wilk Post-Test	0.9094	0.0255	Not Normal ($p \leq 0.05$)
Shapiro-Wilk Delta (Pre - Post)	0.9581	0.3566	Normal ($p > 0.05$)
Paired t-test	3.2215	0.0035	Significant difference ($p < 0.05$)
Cohen's d	0.6317		Medium effect (0.2–0.8)

The boxplot visualization (Figure 2b) illustrates a downward shift in anxiety score distribution following the VR intervention, with a lower median, reduced variability, and fewer outliers in the post-test. This suggests that the intervention not only lowered average anxiety levels but also produced more consistent outcomes across participants. A Shapiro–Wilk test was then performed on the score differences ($\Delta = \text{Pre-test} - \text{Post-test}$), yielding $W = 0.9581$ and $p = 0.3566$, indicating that the data were normally distributed and met the parametric test assumption ($p > 0.05$). A paired-sample t-test showed a significant reduction in STAI-T anxiety scores following the VR intervention ($t(25) = 3.22$, $p = 0.0035$), with mean scores decreasing from 55.00 ($SD = 6.32$) to 47.25 ($SD = 6.85$). The effect size (Cohen's $d = 0.63$) indicates a moderate-to-large impact, suggesting that VR substantially reduced participants' anxiety (Table 2).

This study demonstrates that a space travel-themed virtual reality (VR) application significantly reduced anxiety in boys undergoing circumcision. The mean STAI-T score decreased by 3.46 points, with an effect size of Cohen's $d = 0.63$, indicating a moderate-to-large and clinically meaningful impact. These findings are consistent with previous studies reporting the effectiveness of group-facilitated VR interventions in lowering anxiety (Ayan & Şahin, 2023; Yeniay *et al.*, 2023). This consistency with existing literature strengthens the credibility of the present findings and supports the validity of VR as an effective intervention for reducing anxiety. In this study, the VR application was successfully implemented during circumcision, alleviating anxiety in children. These results align with

previous research demonstrating that VR serves as an effective distraction technique during medical procedures to mitigate anxiety (Buyuk *et al.*, 2021; Wu *et al.*, 2022). It presented that VR applications or VR games can shift the patient's focus during surgery.

Research indicates that most hospitalized children undergo painful medical procedures, with 78.2% experiencing at least one, yet only 28.3% receiving interventions to alleviate pain (Stevens *et al.*, 2011). Mandatory medical surgeries can trigger anxiety, pain, fear, and other adverse effects in children, even during recovery, and may lead to long-term consequences that affect their tolerance of future medical procedures (Lambert *et al.*, 2020). Therefore, promoting noninvasive interventions to reduce anxiety in children is essential. VR technology offers an effective pain relief strategy by distracting children from painful experiences through immersive virtual environments. By integrating visual imagery, auditory stimuli, and cognitive engagement, VR not only shifts attention away from anxiety-inducing stimuli but also enhances mood during and after medical procedures.

Conclusion

This study found that a space-adventure-themed Virtual Reality (VR) application effectively reduced anxiety levels in boys undergoing circumcision. The difference in pre- and post-intervention anxiety scores was normally distributed ($p = 0.357$), validating the use of a paired t-test. The analysis showed a significant reduction in anxiety ($p = 0.003$) with a medium effect size (Cohen's $d = 0.63$), indicating a meaningful impact of the VR intervention. These findings confirm

the potential of VR as a practical non-pharmacological approach in pediatric medical procedures, particularly in reducing anxiety and pain through emotional engagement and immersive experiences. Further research is recommended, including control groups, larger and more diverse samples, and physiological measurements and interactive content to strengthen the validity and assess the long-term impact of VR interventions.

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