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E-B Environment - Behaviour Proceedings Journal

AcE-Bs2023KualaTerengganu

https://www.amerabra.org

e-IPH e-International Publishing House Ltd., United Kingdom

11th ASIAN Conference on Environment-Behaviour Studies
Primula Beach Hotel, Kuala Terengganu, Malaysia, 14-16 Jul 2023

Virtual Reality (VR) Simulation for Magnetic Resonance Imaging (MRI) Patient Preparation

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Abstract
This study aimed to compare the effectiveness of virtual reality (VR) simulation as a patient preparation method for Magnetic Resonance Imaging (MRI) examinations. A total of 138 participants were divided into VR and non-VR groups. The study found that anxiety levels were significantly different between the VR group before and during MRI exams (p<.001), but there was no significant difference in the non-VR group (p=.138). Noise, space, and strapping were moderately correlated with anxiety levels. The study suggests that VR could be an accessible pre-medical procedure option, improving patient experience, future treatment planning and reducing costs associated with premature MRI exams.

Keywords: Anxiety, Magnetic Resonance Imaging, MRI Anxiety Questionnaire, Subject Experience Questionnaire, Virtual Reality

DOI: https://doi.org/10.21834/e-bpj.v8i25.4846

1.0 Introduction

Magnetic Resonance Imaging (MRI) has become an essential tool in the medical field over the last three decades. The process involves lying inside a superconducting magnet while coils are placed over the target area to create an image. However, this experience can be challenging for individuals due to the loud noises and the need to remain still for an extended period (Alghamdi et al., 2022). Such circumstances can cause anxiety, especially in people with claustrophobia, leading to poor image quality, early termination of examinations, or the need for sedation. MRI technologists report that anxiety is a common issue affecting respiratory rate, peristalsis, and fluid flow, making it harder for patients to manage small spaces. A recent study by Napp et al. (2021) found that patients experiencing anxiety had difficulty coping with the noise of the scanner and the feeling of confinement. Assisting patients with anxiety management during scans can be challenging. While various therapies have been explored, they are often time-consuming, difficult to implement, or expensive. Therefore, there is a growing demand for non-medication-based tools, particularly for patients with claustrophobia (Nakarada-Kordic et al., 2020). Virtual reality (VR) simulation is one such tool that emphasises understanding and communication, providing a safe

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DOI: https://doi.org/10.21834/e-bpj.v8i25.4846

and effective solution. Thus, this study aimed to compare the effectiveness of virtual reality (VR) simulation as a patient preparation method for MRI examinations.

2.0 Literature Review

It is important to note that claustrophobia during MRI scans can vary depending on the type of scan and scanner design. Specifically, head or neck scans tend to induce claustrophobia more frequently, with approximately 37% of patients scheduled for MRI scans showing signs of the condition (Almutlaq, 2018). The physical environment of the MRI scanner can cause patients to experience anxiety, fear, tension, and panic due to the machine's closed, narrow, and long bores. Additionally, the acoustic noise during the procedure can be bothersome and make communication difficult. It is worth mentioning that the MRI environment can cause distressing sensations such as an extended duration, temperature, and stress related to restricting movement within the MR system.

Moreover, patients may also experience sensory deprivation during the examination, leading to anxiety. It is essential to know that the direct contact of radio frequency (RF) coils with the patient's skin can increase temperature due to MRI exposure, leading to risks such as exhaustion, heat stroke, and anxiety (Kim et al., 2016). However, some strategies can be implemented to reduce anxiety and make the experience more comfortable for patients. For instance, patients can be adequately prepared, and distraction techniques such as VR simulation, music, or fragrance can be used during the procedure (Tugwell et al., 2018 & Kılıç et al., 2021). Studies have shown that VR simulation can effectively reduce anxiety and stress in children undergoing MRIs and as a research tool in various medical fields. Patients can become more comfortable with the scan after spending time in it, which can improve the quality of their experience. While mock MRI machines are a cost-effective way to provide a realistic MRI experience, they require a dedicated space and the presence of a technician, health care assistant, or therapist.

3.0 Methodology

3.1 Sample selection

This prospective cohort study, conducted from October to December 2022, included patients aged 18-70 years who had never undergone an MRI, had no neurological or psychiatric illness, and could communicate in English. Exclusion criteria were drug usage history, need for sedation, pregnancy, or emergency referral. A total of 138 patients participated in the study, with 69 receiving VR simulation (referred to as the VR group) and the other 69 not receiving it (referred to as the non-VR group). The grouping was randomly assigned using a between-subject design, and both groups were given two questionnaires to answer. The reliability of the questionnaire was assessed using Cronbach's alpha coefficient. For the MRI anxiety questionnaire (MRI-AQ), the reliability score was 0.80, while for the MRI subject experience questionnaire (MRI-SEQ), it was 0.74. These results indicate high reliability and an acceptable index.

3.2 MRI Anxiety Questionnaire (MRI-AQ)

Both groups were given a questionnaire before and after their MRI examinations. They were briefed on the procedure and given a pre-MRI Anxiety Questionnaire (MRI-AQ) adapted from Ahlander et al., (2016). The results were compared between the two groups to determine the significant difference in anxiety levels. The data was gathered using a four-point Likert scale. A higher score indicates a more severe level of anxiety, whereas a low score implies the absence of anxiety.

3.3 MRI Subject Experience Questionnaire (MRI-SEQ)

All 138 participants in both groups were asked to rate the contributing factors associated with their anxiety levels using MRI-SEQ. The questionnaire was distributed after the MRI examination, and the participants were asked to rate the factors on a 5-point Likert rating scale ranging from 1 (strongly disagree) to 5 (strongly agree). The MRI-SEQ, adapted from Thorp et al., (1990), aimed to identify the common factors contributing to anxiety.

3.4 Non-Virtual Reality (Non-VR) Group

Prior to the MRI procedure, the patient must complete the pre-MRI-AQ and receive proper instructions from the researchers. During the examination, they must remain awake to experience the MRI bore fully. This involved lying down on the MRI table, positioning the table, moving the table into the gantry, beginning acquisition, removing the table from the gantry, and lowering the table to complete the scan. After the scan, the patient must complete two questionnaires: post-MRI-AQ and MRI-SEQ.

3.5 Virtual Reality (VR) Group

Patients completed a pre-MRI Anxiety Questionnaire before starting the VR video simulation. The simulation mimics the actual MRI environment, allowing patients to experience the entire procedure, from entering the examination room to lying down and sliding their head or feet into the MRI scanner until the MRI table slides out. Patients were instructed on how to use the VR device before the simulation started. After completing the simulation, patients changed into hospital gowns and removed all metallic items before the actual MRI examination. During the scanning, patients were instructed to remain awake. Once the examination was completed, patients filled out post-MRI questionnaires before leaving the MRI area.

3.6 Statistical Analysis

The data were analysed using SPSS Version 29 software. The Wilcoxon Signed-Rank Test was used to determine the effectiveness of VR simulation before and after MRI examination. The means of anxiety and relaxation levels for the VR and non-VR groups were compared using a T-test. Factors contributing to anxiety were determined with the Spearman Correlation. Results with a p-value lower than 0.05 were considered statistically significant. The Faculty Ethics Research Committee at UiTM's Faculty of Health Sciences has approved the ethics for this study (FERC/FSK/MR/2022/0363). Participants were provided with a physical consent form and agreed to participate in the study of their own free will.

4.0 Findings

Table 1 shows that the majority of participants in the VR group were female (59%). Most participants were between 41 and 50 (36%), followed by 28% aged between 31 and 40. Most participants were married (58%) and of Malay ethnicity (49.3%). Islam was the most common religion (53.6%). Most had an SPM certificate (41%). In the non-VR group, most participants were female (52%) and aged between 41 and 50 (35%). The majority were married (75%), followed by Malays (61%), who mainly were Muslims (61%). Most participants had a diploma (41%).

Table 1. Demographic variables in the VR and non-VR groups.

Variables	Categories	VR Group Frequency (%)	Non-VR Group Frequency (%)
Gender	Male	28 (41%)	33 (48%)
	Female	41 (59%)	36 (52%)
Age group	18- 30	7 (10%)	5 (7%)
	31 – 40	19 (28%)	22 (32%)
	41 – 50	25 (36%)	24 (35%)
	51 – 60	12 (17%)	16 (23%)
	> 61	6 (9%)	2 (3%)
Marital status	Single	17 (25%)	10 (15%)
	Divorced	12 (17%)	7 (10%)
	Married	40 (58%)	52 (75%)
Ethnic	Malay	34 (49%)	42 (61%)
	Chinese	19 (28%)	14 (20%)
	India	13 (19%)	10 (15%)
	Others	3 (4%)	3 (4%)
Religion	Islam	37 (54%)	42 (61%)
	Buddha	18 (26%)	11 (16%)
	Hindu	11 (16%)	10 (14%)
	Christian	3 (4%)	6 (9%)
Highest Education	UPSR	1 (1%)	1 (1%)
	PMR	1 (1%)	1 (1%)
	SPM	28 (41%)	24 (35%)
	STPM	2 (3%)	0 (0%)
	Diploma	17 (25%)	28 (41%)
	Bachelor's degree	18 (26%)	14 (20%)
	Master	2 (3%)	1 (1%)
	PhD	0 (0%)	0 (0%)

Table 2 presents the anxiety levels of the VR group participants before and during the MRI procedure. Ahlander et al. (2016) categorised anxiety levels as low (1.00 – 2.00), moderate (2.10 – 3.00), or high (3.10 – 4.00) based on the mean score of the MRI-AQ. Before the MRI, most participants in the VR group exhibited high anxiety levels, with panic being the highest mean score at 3.54. Other anxiety-inducing factors were fear (3.51), the need for more information (3.49), and the desire to leave the MRI room (3.46). Few participants experienced palpitations before the MRI (2.74), the lowest anxiety level. During the MRI, most participants still required more information (2.64) and felt worried (2.57). Some had to force themselves to manage the situation (2.52) and needed support and encouragement (2.52). For the non-VR groups, most participants reported high anxiety levels before their MRI examination. Their mean score of 3.19 indicated they needed self-control during the procedure. Participants also experienced worry and fear beforehand (3.51) and felt panicked and needed support and encouragement (3.49, 3.48). Breathing difficulties were common (3.46), and participants felt unsafe (3.25). Meanwhile, the non-VR group participants reported significant anxiety during the MRI examination. The highest mean score of 3.77 indicated a need for more comprehensive information, while a mean score of 3.67 showed that participants felt worried and unable to relax beforehand. They also had to manage the situation forcefully (3.64) and required self-control during the examination (3.58). Participants preferred companionship, felt fear, and believed they could control the situation, with a mean score of 3.57. Palpitations were less common, with a mean score of 3.55; some participants needed support and encouragement (3.54).

Table 2. Anxiety levels between the VR and non-VR groups before and during the MRI procedure.

Items	VR Group						Non-VR Group					
	Before			During			Before			During		
	Mean	SD	Level of Anxiety	Mean	SD	Level of Anxiety	Mean	SD	Level of Anxiety	Mean	SD	Level of Anxiety
1. I feel that I can control this situation	3.17	0.68	High	2.09	0.68	Low	3.19	0.71	High	3.57	0.49	High
2. I had palpitation	2.74	0.92	Moderate	2.16	0.67	Moderate	3.29	0.68	High	3.55	0.50	High
3. I found it hard to breath	3.29	0.67	High	2.32	0.72	Moderate	3.46	0.58	High	3.61	0.49	High
4. I was afraid	3.51	0.50	High	2.13	0.68	Moderate	3.51	0.58	High	3.57	0.49	High
5. I want to come out	3.46	0.53	High	2.25	0.67	Moderate	3.43	0.58	High	3.61	0.49	High
6. I panicked	3.54	0.56	High	1.96	0.72	Low	3.49	0.56	High	3.61	0.49	High
7. I do not relax	3.30	0.67	High	1.45	0.50	Low	2.86	0.86	Moderate	3.67	0.47	High
8. I don't feel safe	3.42	0.58	High	1.33	0.46	Low	3.25	0.62	High	3.61	0.49	High
9. I worried in advance	3.43	0.63	High	2.57	0.74	Moderate	3.51	0.53	High	3.67	0.47	High
10. I don't feel calm	3.38	0.57	High	1.51	0.50	Low	2.80	0.60	Moderate	3.59	0.49	High
11. I had to force myself to manage the situation	3.43	0.55	High	2.52	0.76	Moderate	3.52	0.50	High	3.64	0.48	High
12. Self-control was required when going through his examination	3.43	0.65	High	2.39	0.79	Moderate	3.55	0.55	High	3.58	0.49	High
13. I needed support and encouragement	3.39	0.60	High	2.52	0.80	Moderate	3.48	0.50	High	3.54	0.50	High
14. I wished to have someone with me	3.43	0.58	High	2.29	0.79	Moderate	2.97	0.78	Moderate	3.57	0.49	High
15. I need more detailed information	3.49	0.53	High	2.64	0.89	Moderate	3.06	0.63	High	3.77	0.42	High

4.1 Comparison before and during MRI examination.

Wilcoxon Signed Ranked Test was done before and during the MRI examination for the VR group. This test was performed to evaluate the effectiveness of VR simulation as patient preparation in terms of anxiety level by analysing the score of pre-MRI-AQ and post-MRI-AQ, which consist of the same questions. There was a significant difference in anxiety level as the p-value is less than p<.05, p=.01 for both pre-and post-MRI-AQ. Meanwhile, the non-VR group indicates no significant difference in anxiety level as p>.05, p=.138.

4.2 Comparison of anxiety level for both groups.

To compare the anxiety level for both groups during the MRI procedure, T-test was used to compare the mean score for both groups. Paired sample T-test, both during MRI procedures, (mean=22.01, SD=4.02). There was a significant difference with p<.05. Meanwhile, the t=45.487 is greater than the critical value, which is 1.668, which manifests as greater evidence for the significant difference in anxiety level post-MRI procedure for VR versus the non-VR group.

4.3 The correlation of factors that contribute to the anxiety in both groups using MRI-SEQ

According to Spearman correlation, noise and anxiety levels have a positive and moderate correlation (rs = 0.696, p <.001). Additionally, there is a moderate correlation between space and anxiety level (rs = 0.493, p <.001), followed by a moderate correlation between strapping and anxiety level (rs = 0.444, p <0.001). A weak positive correlation was found between keeping still and anxiety (rs = 0.149, p = 0.081) and between being alone and anxiety (rs = 0.147, p = 0.084). Comfort was also found to have a weak correlation with anxiety level (rs = 0.122, p = 0.155). Lastly, a weak correlation was reported between time spent in the scanner and anxiety level (rs = 0.109, p = 0.204).

5.0 Discussion

5.1 The effectiveness of VR simulation as patient preparation before and after MRI examination.

Patients who reported less anxiety after the VR simulation mentioned feeling more in control inside the MRI gantry. Previous studies by Nakarada-Kordic et al. (2020) and Yakar and Pirinçci (2020) found that providing patients with information significantly decreased anxiety levels. Similarly, Tazegul et al. (2015) found that the VR simulation group had significantly lower anxiety scores than the control group. Therefore, providing patients with information, including VR simulation, prior to an MRI can help alleviate their anxiety. Tazegul et al. (2015) discovered that cortisol levels in a patient's blood were compared before and after an MRI exam. These findings support the need for MRI exposure before the examination, as anxiety levels can affect brain response dynamics and overall physical state. Patients' stress and anxiety levels can predict the possibility of scan repeats. According to Klaming et al. (2015), electrophysiology was used to determine patients' anxiety levels during the examination. They concluded that anxiety levels were highest at the beginning of the scan, with a peak occurring when the table moved within the magnet bore. Scanning patients in a prone position, allowing them to look outside the magnet bore, is another technique that could reduce anxiety levels. Previous research has also suggested that VR can help patients cope with the fear and discomfort of undergoing an MRI. Hudson et al., (2022) discovered that VR can alleviate anxiety and improve compliance. Duncan et al. (2018) investigated the design of VR intervention, its intended use, and how its success has been evaluated.

5.2 The difference in post-anxiety levels in the experimental (VR group) and with the control group (non-VR group).

Although technologists may deem MRI safe, patients often report feeling anxious during the process and may even experience claustrophobia due to the enclosed form of the gantries. After analysing the responses from the anxiety questionnaire, it was found that

some participants experienced moderate to high anxiety when answering questions about worry in advance and had to force themselves to manage the situation. This suggests that the VR simulation only partially convinced all the participants, and some participants provided helpful ideas to enhance the overall quality of the VR experience. Kiliç et al. (2021) and Nakarada-Kordic et al. (2020) have reported that VR is as effective as traditional methods in preparing patients for their MRI experience. After their MRI examinations, the VR group reported feeling moderate to highly anxious, possibly due to miscommunication with the technologist. According to studies by Bolejko and Hagell (2021), patients who received proper information before their MRI experienced significantly less anxiety than those who did not receive such information. However, the studies also included counselling and written information, making it difficult to determine its exact effect alone. Nevertheless, providing patients with information before an MRI examination is important and leads to higher satisfaction rates than those who do not receive proper information. The data from Tugwell et al. (2018) showed that all participants in the control group experienced moderate to extreme anxiety prior to their MRI examination. This could be attributed to their first time undergoing an MRI, not knowing what to expect, and a lack of information about the procedure. Additionally, participants had a limited understanding of the MRI technique. They received insufficient information from the technologist, leading to feelings of helplessness and uncertainty, increasing their anxiety levels.

5.3 Correlation of anxiety level with the associated factors

This study found that anxiety levels are moderate to weakly correlated with certain factors. Most participants reported that the noise produced by the gradient coils was the most significant factor contributing to their anxiety, with a moderate correlation. Despite the provision of noise-cancelling headphones, they were not entirely effective in cancelling the loud noise. The confined space inside the MRI gantry was the second most significant contributing factor. Although this study used closed MRI systems, some participants found them uncomfortable, with 92.8% reporting anxiety due to the confined space. Additionally, the MRI bore was only sixty centimetres wide, causing additional anxiety for individuals with larger body sizes. Nguyen et al. (2020) also found positioning patients with large body habitus inside the MRI bore challenging. However, advancements in MRI scanner technology may alleviate anxiety issues by improving scanner designs. A short MRI bore was associated with a low anxiety incident rate of 0.7% in over 12,000 consecutive patients. The study found a weak correlation between patient discomfort during the MRI examination and factors such as the hard and small MRI table and the prolonged time spent inside the gantry. Another study by Madl et al. (2022) suggested that extended procedure times could lead to uncomfortable patient conditions, potentially triggering phobias and anxiety. Anxiety has also been found to cause scan termination during head and neck MRIs. Additionally, lying supine may cause feelings of confinement within the narrow gantry, while the prone position allows participants to face the opening of the bore and see the light. This simple adjustment may help alleviate anxiety in most patients, but it may not be possible in certain medical situations. It is important to note that this study only included participants who were unwell and had never undergone a real MRI exam. The study did not consider the correlation between anxiety levels, specific scanning parts, or body mass index. While VR simulation can result in adverse effects like vertigo, confusion, and anxiety, it is difficult to determine if this discomfort was caused by exposure to VR or the MRI experience itself. A more extensive study on a representative sample of patients is crucial to further investigate the effectiveness of VR simulation in preparing patients for MRI exams, reducing the number of aborted scan sessions, and improving treatment planning.

6.0 Conclusion and Recommendations

Virtual Reality (VR) technology has the potential to become a feasible alternative that is easier to access before undergoing any medical procedure. With a few minor adjustments, VR simulation could be used in settings other than medical imaging procedures. This could improve patient satisfaction with potentially stressful medical examinations, aid in future treatment planning, and reduce costs by reducing the number of prematurely terminated MRI exams.

Acknowledgement

The authors would like to thank all the participants and the field team for contributing to the study's data collection.

Paper Contribution to Related Field of Study

This study serves as a trial for a bigger project. Virtual Reality (VR) offers a fresh approach for technologists to use on patients who have already undergone an MRI, as they are more familiar with it. This can help reduce the number of cancelled scan sessions, improving the patient's treatment planning.

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