# Virtual Reality Pre-Scan Simulation to Reduce MRI-Related Anxiety and Improve Scanning Efficiency

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## Abstract

Claustrophobia and anxiety are leading causes of failed or interrupted MRI procedures, representing a significant cost burden on imaging services. This study investigated the effectiveness of a custom Virtual Reality (VR) pre-scan simulation in reducing MRI-related anxiety compared to a video-and-guided-meditation intervention and a standard control condition. Eighteen participants were allocated to three groups (n = 6 each). Anxiety was measured using the Claustrophobia Likert Questionnaire (CLQ) and the MRI Anxiety Questionnaire (MRI-AQ) before and after the procedure. The VR group demonstrated the greatest anxiety reduction, with a mean post-intervention score of 1.322 (SD = 0.281) versus 1.778 (SD = 0.202) in the control group. Paired t-tests confirmed statistical significance: Pre-MRI vs. Post-VR ($p = 0.0077$) and Control vs. Post-VR ($p = 0.0107$). These findings indicate that immersive VR simulation is significantly more effective than both standard preparation and video-based methods in reducing MRI anxiety, with implications for reducing sedation rates and improving scanner throughput.

## 1. Introduction

Magnetic Resonance Imaging (MRI) is a critically important diagnostic tool for a wide range of medical disciplines. Yet its clinical utility is undermined by a significant proportion of patients who experience great difficulty in tolerating the psychological challenge of the procedure. Up to 15% of patients experience claustrophobia severe enough to cause scan failure, premature termination, or the need for pharmacological sedation (Nguyen et al, 2020, Dewey et al., 2007). Worldwide there are estimated to be in excess of 100 million MRI scans per year, with one study quantifying the cost of claustrophobia-related failures at an estimated €1 billion in Europe alone (Enders et al, 2011).

The MRI environment is inherently challenging for anxious patients. The narrow bore (typically 60 cm diameter), loud gradient coil noise (up to 103 dB for certain sequences), prolonged scan durations, and physical immobilisation combine to create a highly stressful sensory environment (Sarji et al., 1998, Iwan et al.,2021). Traditional management strategies focused upon patient education or sedation carry significant limitations. Sedation introduces clinical risk, additional cost, and the requirement for anaesthetic staff while education alone can be ineffective (Lawal et al., 2023, Iwan et al., 2021).

Virtual Reality (VR) has emerged as a promising behavioural intervention for anxiety disorders, offering controlled, immersive exposure to feared stimuli. Prior work suggests VR can trigger authentic fear responses and support meaningful anxiety reduction with high patient acceptability (Anderson et al 2023). However, most existing VR applications in MRI have focused on in-scanner distraction rather than pre-scan preparation and familiarisation. This study addresses that gap by developing and evaluating a purpose-built VR simulation of the full MRI experience, deployed before the scan, as a behavioural desensitisation tool..

# 2. Methods

## 2.1. Study Design

This study Bridges the VR1/ VR2 development stages of the model proposed by Birckhead et al (2019). Namely it covers the design/ development and initial efficacy stages of the process. This was a prospective, controlled study with 18 adult participants (aged 18–65) recruited via word of mouth and email. Ethical approval was obtained from the Nottingham Trent University School of Social Sciences Research Ethics Committee (S3REC). Participants with no prior MRI experience were randomly allocated to either the VR intervention (Group B, n = 6) or a video-and-meditation intervention (Group C, n = 6). Those with prior MRI experience formed the control group (Group A, n = 6). All participants subsequently underwent a 20-minute brain MRI scan on a Siemens MAGNETOM Avanto 1.5T scanner.

## 2.2. VR Simulation

The simulation was engineered to elicit authentic physiological and psychological responses by replicating the perceptual experience of an MRI scan. The design encompassed detailed 3D modelling and texturing, full environmental reconstruction, integrated scanner audio, animated clinical hardware, and interactive control systems, all delivered via the Meta Quest 2 headset.

### 2.2.1. Scanner Modelling and Texturing

A high-fidelity digital replica of the Siemens MAGNETOM Avanto 1.5T scanner was constructed in Autodesk 3ds Max, drawing on technical specifications and reference photographs of the physical unit. The scanner model and patient table were both texture-mapped to achieve close visual correspondence with their real-world counterparts.

### 2.2.2. Room and Environmental Design

Beyond the scanner itself, the surrounding MRI room was reconstructed within the virtual environment. Situating the equipment within a convincing clinical space was considered essential for reinforcing the sense of presence; a scanner rendered in isolation would have undermined the ecological validity of the simulation. The complete room context contributed to the immersive quality of the experience.

### 2.2.3. Auditory Simulation

Scanner acoustics were captured using a Zoom H4n Pro recorder positioned in the safe vicinity of the live scanner during active imaging. Seven clinically representative pulse sequences were recorded, A T1-weighted spin echo, a T1-weighted Magnetization-Prepared Rapid Gradient Echo, T2 weighted Half-Fourier Acquisition Single-shot Turbo spin-Echo, a gradient echo field map sequence, a 2D echo-planner diffusion sequence and a T1 weighted gradient echo FLASH sequence. These were selected on the basis of literature evidence identifying them as among the

noisiest, or most clinically relevant, sequences encountered in routine brain MRI (Shellock et al., 1994). The recordings were edited into a continuous 20-minute audio track, programmed to begin 10 seconds after simulated bore entry, matching the temporal structure of a real scan. A virtual buzzer tone was also embedded to replicate the patient alarm function.

#### 2.2.4. Head Coil and Bore Movement

The head coil, a known contributor to the sense of confinement in MRI, was modelled and animated to simulate its lowering and locking sequence, heightening the participant experience of physical constraint. To simulate the transition into the bore, the bore itself was animated to move over a stationary participant. This was a more reliable and consistently replicable method of creating the experience of entering the bore than physically moving the stretcher into a static virtual bore.

#### 2.2.5. Controls and Operator Communication

A two-controller interface managed the simulation. The participant held the left controller, the trigger of which activated a virtual call buzzer mirroring the physical emergency button used in clinical MRI. The operator used the right controller to initiate bore movement and scanner audio; a second press ended the scanning sequence and moved the participant out of the virtual bore. Real-time voice communication was enabled via a WhatsApp audio call running concurrently on the headset. This was a prototyping workaround for the complications of replicating the intercom system standard in clinical MRI suites within the VR software. When the participant pressed the buzzer, the call was automatically unmuted, allowing the operator to respond immediately.

#### 2.2.6. Participant Protocol

Participants reclined on a medical stretcher, donned the Meta Quest 2 headset, and held the left controller as a surrogate call bell. The operator monitored the session in real time via the Meta Quest companion app screen-cast to a mobile device. The complete simulation ran for 20 minutes, matched to the duration of the subsequent MRI scan, providing participants with a temporally representative experience of the full procedure.

### 2.3. Video and Meditation Intervention

Group C watched an iPhone-produced MRI guidance video covering patient preparation, positioning, head coil placement, calling bell function, and a preview of scanner noise. This was followed by a 5-minute guided breathing exercise (4–7–8 technique) sourced from YouTube. Participants were encouraged to use the breathing technique during the scan.

### 2.4. Outcome Measures

Two validated instruments were used. The Claustrophobia Likert Questionnaire (CLQ) established baseline claustrophobic tendency across 26 items on a 0–4 scale (total 0–96, categories: Not Anxious 0–24, Little Anxious 25–48, Moderately Anxious 49–72, Highly Anxious 73–96) (Radomski et al., 2001). The MRI Anxiety Questionnaire (MRI-AQ), a 15-item, 4-point Likert instrument, was administered pre-intervention and post-scan (Ahlander et al., 2016). Selected items were reverse-scored to ensure directional consistency. Statistical analysis employed independent-samples t-tests (Welch correction for unequal variances) using MATLAB, with significance set at $p < 0.05$.

# 3. Results

## 3.1. Demographic Characteristics

Group A (Control) had a mean age of 26.0 ± 2.40 years (1M, 5F). Group B (VR) had a mean age of 25.5 ± 1.97 years (3M, 3F). Group C (Video) had a mean age of 27.0 ± 3.46 years (4M, 2F). All control participants had prior MRI experience; no VR or video participants did.

| Group | Mean CLQ Score | Anxiety Level | SD |
|---|---|---|---|
| Control (A) | 35.00 | Little Anxious | ±18.24 |
| VR (B) | 23.67 | Not Anxious | ±18.47 |
| Video (C) | 22.83 | Not Anxious | ±17.71 |

*Table 1: CLQ Baseline Scores by Group.*

## 3.2. Pre MRI Anxiety Score (baseline)

Group A (Control) had a mean age of 26.0 ± 2.40 years (1M, 5F). Group B (VR) had a mean age of 25.5 ± 1.97 years (3M, 3F). Group C (Video) had a mean age of 27.0 ± 3.46 years (4M, 2F). All control participants had prior MRI experience; no VR or video participants did.

| Group | Pre-MRI Mean (SD) | Post-Intervention Mean (SD) | Change |
|---|---|---|---|
| Control (A) | 1.70 (0.38) | 1.78 (0.20) | +0.08 |
| Video (C) | 1.76 (0.33) | 1.56 (0.43) | −0.20 |
| VR (B) | 1.88 (0.38) | 1.32 (0.28) | −0.56 ✓ |

*Table 2: Pre- and Post-Intervention MRI-AQ Scores.*

## 3.3. Post Intervention Anxiety and Statistical Analysis

The VR group achieved the largest reduction in anxiety (mean post-scan score 1.322, SD = 0.281). The video group showed a moderate reduction (1.566, SD = 0.438), while the control group showed a slight increase (1.778, SD = 0.202), consistent with the natural anxiety-elevating effect of the scan itself. T-test results are summarised in Table 3.

| Comparison | t-statistic | Df | p-value | Significant? |
|---|---|---|---|---|
| Pre-MRI vs. Post-MRI (Control) | 0.087 | 15.14 | 0.9315 | 0.9315 |
| Pre-MRI vs. Post-Video | 1.140 | 7.21 | 0.2907 | No |
| Pre-MRI vs. Post-VR | 3.295 | 10.38 | 0.0077 | Yes ✓ |
| Post-MRI vs. Post-Video | 1.085 | 7.07 | 0.3137 | No |
| Post-MRI vs. Post-VR | 3.203 | 9.05 | 0.0107 | Yes ✓ |

*Table 3: Paired T-Test Results.*

The VR intervention was the only condition to produce a statistically significant reduction in anxiety relative to both the pre-scan baseline ($p = 0.0077$) and the post-scan control group ($p = 0.0107$). Neither the video intervention nor the standard MRI experience alone produced significant anxiety changes.

## 4. Discussion

The results confirm that immersive VR pre-scan simulation is significantly more effective than both standard MRI preparation and a combined video-and-breathing-exercise intervention in reducing procedure-related anxiety. This finding is consistent with the broader literature on VR for anxiety disorders (Anderson et al., 2023), and extends it specifically to the pre-scan preparation context, which has received comparatively less attention than in-scanner distraction approaches (Hudson et al., 2022).

The mechanism is likely twofold. First, VR delivers a form of controlled behavioural exposure: by navigating the simulated environment, lying on the patient table, hearing authentic sequence noise, experiencing the bore closing around them, participants are exposed to the stimuli in a psychologically safe setting. This mirrors established exposure-based treatments for specific phobias (Boeldt et al., 2019) . Second, the immersive and interactive nature of VR (place illusion and plausibility illusion (Slater et al., 2009) [40]) provides a qualitatively different level of engagement than passive video viewing, which helps contextualise them the video intervention's non-significant effect despite providing informational content of similar scope.

The slight increase in anxiety observed in the control group from pre- to post-scan (1.70 to 1.78) is noteworthy, suggesting that the MRI experience itself can be anxiety-provoking even for participants without pre-existing anxiety disorder, a finding that underscores the clinical case for pre-scan preparation for a broader patient population, not just those with known claustrophobia.

The simulation's design features, authentic auditory environment, animated head coil, WhatsApp-mediated operator communication, and buzzer functionality, appear to have contributed to ecological validity. Participants who had experienced the VR simulation likely entered the real scan with greater cognitive predictability of the environment, reducing the 'fear of the unknown' component that prior literature identifies as a key driver of MRI anxiety (Törnqvist, et al., 2006).

From a service delivery perspective, the implications are meaningful. Sedation for claustrophobic patients carries direct costs (anaesthetist time, recovery space, medication) and indirect costs (longer slot times, scheduling complexity). A VR pre-scan simulation, once developed, is a low-marginal-cost, repeatable, non-pharmacological intervention that could be implemented as a standard pathway for first-time or anxious patients. This would directly address the estimated €1 billion annual productivity loss from claustrophobia-related scan failures across Europe (Nguyen et al., 2020).

## 5. Limitations and future work

Several limitations must be acknowledged. The sample (n = 18, primarily university students aged 22–32) was small and demographically narrow, limiting generalisability to older or more clinically anxious populations. The relatively low baseline CLQ scores suggest participants were generally not highly claustrophobic, which may have attenuated the observed effect sizes; a larger effect could be expected in a clinical population with diagnosed MRI phobia. Allocation was not fully randomised (prior MRI experience determined control group membership), introducing a potential confound. The audio recording equipment was positioned too far from the scanner, resulting in some sound attenuation relative to validated reference levels (Shellock et al., 1994).

There is also a need to calibrate audio volume and frequency to the specifics of the headset being used. Future work should include: (i) a larger randomised controlled trial in a clinical MRI setting with patients referred for diagnostic scanning; (ii) objective physiological measures (heart rate, cortisol) alongside self-report instruments; (iii) inclusion of patients with formally diagnosed claustrophobia or anxiety disorders; and (iv) investigation of whether VR preparation reduces measurable rates of scan interruption, sedation use, and image quality degradation.

## 6. Conclusion

This study provides evidence that a purpose-built VR pre-scan simulation can significantly reduce MRI-related anxiety, outperforming both standard preparation and a video-and-meditation intervention. The VR group demonstrated a statistically significant reduction in anxiety scores ($p = 0.0077$), while no significant effect was observed for the video or control conditions. These findings support the clinical adoption of VR pre-scan preparation as a patient-centred, non-pharmacological strategy to improve the MRI experience, reduce failed scans, and decrease reliance on sedation. Further research with clinical populations and larger samples is warranted to confirm and extend these findings.

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