Designing "Mission Control": An Immersive VR Simulation to Improve Pediatric MRI Experiences

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Abstract

Children's participation in neuroscience and neuroimaging research is often limited, especially when magnetic resonance imaging (MRI) is involved, due to confined spaces, loud noises, and the need for prolonged immobility. Distraction techniques informed by child psychology professionals and MRI technicians can alleviate anxiety and fear. When distraction is insufficient, sedation or anesthesia may be required, increasing costs, posing potential side effects (e.g., adverse reactions to sedation or anesthesia), and limiting research inclusivity. Moreover, children often exhibit increased head motion in the scanner, compromising image quality and potentially leading to diagnostic errors or unusable data. Our project outlines the development of Mission Control, an innovative virtual reality (VR) simulation designed to address the challenges of pediatric brain MRI procedures by familiarizing children aged 6 to 12 years with the MRI environment. Mission Control aims to reduce anxiety and teach children to remain still during scans, and is freely available, addressing the limited availability of VR MRI applications outside of research settings. The simulation features a rocket landing mission on the moon, where children must maintain stillness to reach their destination. Head tracking is used to train stillness, while audiovisual cues and narration transform the MRI experience into an engaging adventure. To ensure content appropriateness, we replicated MRI procedures and facilities from our Cerebral Imaging Centre, and consulted MRI specialists, designers, and mental health researchers during the design phase. Future directions include conducting a pilot study to evaluate the accessibility, feasibility, and preliminary efficacy of the simulation in a research setting.

KEYWORDS: Magnetic resonance imaging (MRI), Virtual reality (VR), Pediatrics, Children, Non-invasive nonpharmacological tool, Neuropediatrics research

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Magnetic resonance imaging

Magnetic resonance imaging (MRI) has become a vital tool in modern medicine for detecting and diagnosing various diseases, particularly those affecting soft tissues (van Beek et al., 2019). Optimal MRI performance requires the generation of strong, homogeneous, and non-interfering magnetic fields. This has shaped the design of MRI scanners into a cylindrical, body-sized tube that is open at both ends. However, the confined space within the MRI gantry, combined with the nature of the procedure, can often induce discomfort in patients, including unpleasant feelings such as anxiety and claustrophobia (Munn & Jordan, 2011). In children, those feelings are hard to manage, and may lead to short-term effects such as pain, discomfort, crying, and poor cooperation, as well as long-term effects including heightened fear, altered pain perception, the development of phobias, and avoidance of medical care, all causing difficulties during future medical experiences (Alexander, 2012; Malviya et al., 2000).

Such challenges often require additional resources, such as the need to sedate noncompliant pediatric patients to complete imaging procedures (Munn & Jordan, 2013; Tyc et al., 1995). Sedation of pediatric patients is accompanied by considerable costs to the healthcare system, long waiting lists, and, occasionally, health risks and longer stays at the hospital (Anwar et al., 2022; Stunden et al., 2021).

Virtual Reality to improve pediatric MRI

Virtual reality (VR) technology has emerged as a promising tool in healthcare, with the potential to create immersive and engaging environments (Kouijzer et al., 2023). The effectiveness of VR in preparing children for MRI scans has been a topic of investigation over the last decade. In 2017, a pioneering study (Ahmad Zamri, 2017) found that a 10-minute VR session helped 91.3% of children aged 4–6 to complete an MRI, compared to 66.7% with play therapy in a retrospective analysis. In a scoping review, Hudson et al. (2022) identified four VR studies targeting pediatric MRI experiences: two aimed at pre-scan preparation to achieve compliance (Ashmore et al., 2019; Liszio & Masuch, 2017), while the others investigated the use of VR as a distraction technique during mock-scanning (Garcia-Palacios et al., 2007) or through a prototype intended for future in-scanner implementation (Liszio et al., 2020). To date, the use of VR applications inside the scanner remains undocumented, likely due to high costs, the limited availability of MRI-compatible non-metallic systems, and the restricted space between the participant's head and the head coil for accommodating a headset. Taken together, these studies generally reported reduced anxiety and improved scan success, although effects varied in duration. Stunden et al. (2021) conducted a randomized controlled trial comparing a VR simulation app, a mock scanner, and a standard manual, finding that both the VR simulation and the mock scanner outperformed the preparatory manual in reducing anxiety and improving scan success, though no significant difference was observed between them. However, they noted that a single session may be insufficient and recommend multi-day preparation. Yamada-Rice et al. (2023) showed that children under six responded better to multimodal play and storytelling-based preparation than traditional informational or expository methods, highlighting the value of narrative elements in improving scan success.

Taken together, the evidence above suggests that VR can effectively reduce anxiety in children undergoing MRI by providing a safe, engaging environment, improving compliance and reducing the need for sedation. Positive effects were observed across all studies, even though the designs and tools differed: some used a simple VR game mimicking the MRI room (Ahmad

Zamri, 2017), while others combined exposure therapy, gamification, education, and play therapy with input from children across age groups during design, development and testing (Liszio & Masuch, 2017). One study relied on 360° video to replicate the MRI journey, complemented by a preparatory book (Ashmore et al., 2019), while another used explanatory 360° videos to introduce the team, facilities, and MRI procedures, with the addition of a mini-game to train emotional regulation and a motion sensor headband to measure stillness (Stunden et al., 2021). In contrast, Yamada et al. (2023) developed a multimodal play and storytelling-based play kit that integrated storytelling, physical play, mixed reality and VR to familiarize children with the scanner, its noises, the radiographer's role, the MRI procedure, and strategies to remain calm and still. Collectively, these diverse approaches highlight the versatility of VR interventions in preparing children for MRI.

Moreover, VR may be more suitable than mock scanners, which, though they have been shown to reduce distress (Anwar et al., 2022; Thestrup et al., 2023), are costly, space-consuming, and may paradoxically cause increased distress (i.e., sensitization) with repeated exposure (Lueken et al., 2012).

Designing Mission Control, an MRI VR simulation

Our review of VR applications for MRI preparation highlighted that few incorporate storytelling elements (Hudson et al., 2022; Stunden et al., 2021; Yamada-Rice et al., 2023), despite the benefits of narrative for children's communication, knowledge retention, imagination, and emotional development (Ramamurthy et al., 2024). When used, storytelling is often focused on isolated aspects of the MRI procedure, such as briefly familiarizing children with the MRI room and scanner interior. Integrating storytelling in the entire MRI experience—including steps like patient reception, metal screening, and changing rooms—could offer a more immersive introduction to the hospital environment and potentially enhance children's ability to anticipate and cope with the examination. Among the few applications that span the full MRI procedure, Ashmore et al. (2019) developed a mobile app, a preparation book, and a sequence of 360° panoramic videos covering the full MRI journey. Although their approach provided a detailed visual walkthrough of the process, it did not incorporate storytelling nor strategies to actively support stillness training.

To address these limitations, here we outline the methodology behind Mission Control, a novel immersive, storytelling-based VR simulation designed to prepare children for MRI scans. The simulation covers the entire MRI journey—from arrival at the facility to the completion of image acquisition—and includes a stillness training module with real-time audiovisual feedback. In addition to educating and familiarizing children with the MRI procedures, Mission Control aims to reduce distress and motion-related artifacts, thus supporting the mental well-being of pediatric patients.

Research Insights Driving VR Development

Rationale for VR Development

Consistent challenges were observed by the author, LS, and other MRI technicians during pediatric brain MRI scans conducted at the Cerebral Imaging Center (CIC) at the Douglas Research Centre. Two primary difficulties were identified: (1) ensuring that children enter the MRI scanner and remain calm, and (2) maintaining head stillness for durations of up to 30 minutes. In the most common scenario, children initially consented to enter the scanner but became agitated upon hearing the first MRI noise. As a result, numerous scans had been interrupted or rendered incomplete, with financial losses estimated at up to $600 CAD per hour—excluding participant-related costs such as parking, meals, and time.

To address these issues, various techniques were trialed by the CIC MRI team. Storytelling strategies and environmental modifications were implemented to enhance children's engagement, as depicted in Figure 1. The medical setting was modified using thematic covers, decorative posters, and child-friendly motifs—such as a spaceship theme, which had shown promise in other pediatric contexts (Oh et al., 2025). Although these methods improved initial cooperation, sustained engagement was not consistently achieved.

Once children were inside the scanner, efforts were made to encourage stillness through auditory feedback (e.g., "Don't move your feet.") and visual distractions such as videos or YouTube channels projected via mirror systems. However, due to the loud acoustic environment of MRI scanners, these visual stimuli were sometimes insufficient. While some children remained engaged, others still experienced anxiety due to the persistent noise. Additionally, it became clear that many children lacked a precise understanding of what it means to "stay still", highlighting the necessity of explicitly teaching and reinforcing this behavior. This gap was also evident during mock-scanner sessions, which were effective for familiarization but insufficient for training immobility.

Given children's increasing familiarity with digital technologies, immersive tools were hypothesized to offer a more effective solution. In this context, the use of virtual reality was considered a promising avenue. It was expected that VR could enhance engagement, provide real-time motion feedback, and support more effective training. Moreover, it was hypothesized by our team that enhancing tolerability and engagement could support the inclusion of neurodivergent children, reduce reliance on sedation, and contribute to a broader availability of pediatric imaging data. Additionally, offering caregivers a preview of the MRI environment could ease the process of obtaining informed consent for research participation.

While several existing MRI-focused VR applications were tested (e.g, Khora Virtual Reality Simulation, Cineon Virtual Reality MRI Scanning Experience), significant shortcomings were identified. These tools were not specifically designed for children, frequently lacked integrated storytelling elements, failed to replicate key sensory aspects of the MRI environment (such as scanner noise and spatial proximity), and often did not deliver actionable feedback on head motion. Rather than providing a comprehensive and unified experience, they typically addressed individual components in isolation. Additionally, most of the accessible simulations found online had been developed by private companies and were marketed at high costs, with average license fees exceeding $5,000 CAD. They also lacked empirical validation and offered limited control options for the VR operator. The majority of VR tools identified in our literature review were inaccessible outside of their initial research context.

These constraints further reinforced the need for a tailored, evidence-based VR intervention designed specifically for pediatric MRI preparation and stillness training.

Planning

This project was a collective effort carried out in multiple phases. The conceptualization and development of an initial low-fidelity prototype took place within 24 hours during a hackathon (https://www.mcgillxr.ca/past-events), followed by the refinement and development of a more polished and functional version over 18 months, with continuous improvements through iterative cycles. The Mission Control VR app can be accessed at: https://doi.org/10.17605/OSF.IO/NT4GX.

Figure 2 presents the overall flowchart outlining the development process of Mission Control.

Mission Control Prototype

The prototype of our MRI VR simulation was developed by the authors CD, AES, JS, and NC during the NeuroVR Hackathon 2024, organized by McGillXR. The design process consisted of creating mockups to brainstorm the audiovisual and structural elements of our VR simulation using Excalidraw, an open-source collaborative whiteboard tool. Figure 3 shows the initial design envisioned for this prototype, featuring the rooms and auditory information.

The narrative script, including spoken words and on-screen text, was further developed by the design team (AES, JS) in Notion, a note-taking tool. In the writing and revision process, attention was given to child-friendly instructions that incorporated storytelling aligned with MRI procedures, alongside considerations of pacing, clarity, and audience engagement. The script was continuously revised in a loop as the development team (CD, NC) progressed.

The development team opted to use pre-made digital objects (3D models) in the application, as 3D artists were not available to create custom virtual objects within the timeline. Figure 4 shows examples of these 3D models. To build the initial environment, 3D models were downloaded (e.g., MRI scanner, hospital equipment pack) from the Unity Asset Store, an online library of ready-to-use content. The development team then assembled the virtual hospital scene using Unity 2022.3, a platform for creating interactive 3D experiences. To bring the environment to life, they added features (e.g., movement and audio narration) developed in C# and organized through a timeline of events that defined the sequence and timing of actions within the VR simulation.

The resulting prototype, shown in Figure 4, secured first place in the competition.

Mission Control: Full version development

Building on our success at the hackathon, a new methodology was defined for improving our original prototype. Our approach included the following key steps: (1) Defining new project components and timeline, (2) consultation with co-designers (MRI specialists, UX & content designers, mental health researchers) to inform VR design and narrative, (3) developing the VR environment, (4) iterative refinement through feedback loops with co-designers.

Design refinement and expansion

We consulted with co-author LS, an MRI specialist from the Douglas Cerebral Imaging Centre, to improve our VR simulation. This consultation provided valuable insights into the procedures already in place for children (i.e., narration around the space adventure, use of posters, props, and verbal comparison with elements of the space theme). Our initial prototype was time-based (events occurred and finished at a specific time). We decided to transition to an interactive event-based system, where the user or VR operator must press a button to progress and has the option to replay a sequence to reinforce critical aspects of the procedure. We also wanted to incorporate the ability for the user or VR operator to pause the simulation, and allow the VR operator to see what the user sees. LS also suggested improving the pacing by reducing silence and adding more preparatory rooms to better familiarize children with the full MRI procedure.

The final configuration of the simulation comprised a reception room, an entrance corridor in which participants receive information, a dressing room where they change and remove metal objects, a checking room for the last safety check to ensure no metallic objects are brought in, and the MRI room with the scanner. References from the MRI facilities at the CIC were used to design these different spaces (Figure 5).

We revised the narrative script to incorporate the newly added rooms, additional user interactions—such as removing metallic accessories—and tutorial instructions for operating the VR controllers, while also including key training aspects, such as head coil placement and ear protection, based on expert feedback.

Moreover, we improved the in-scanner virtual experience, designed to encourage stillness by engaging children in a space-themed mission to the moon. Initially, users watched a flat video of the moon, but we upgraded it to a realistic 3D model that simulated a gradual approach as the moon appeared to draw closer. A fixation cross was displayed in front of the user to assess whether they were looking directly at the moon. Audiovisual feedback was provided based on head position: correct feedback was delivered when the user looked at the moon and remained still, while incorrect feedback was triggered by movement or gaze deviation. The simulation concluded with an immersive moon landing.

We included a pause menu in the system that allowed the simulation to be manually paused to enhance user comfort and accommodate potential anxiety. The pause menu also integrated features for customizing the simulation. For example, the duration of the stillness training was set by default to 3 minutes and could be configured to any value between 2 and 30 minutes, meeting the needs of researchers at the Douglas Research Centre while providing sufficient flexibility for all users. Since auditory feedback was manually recorded, it was only supported for trips lasting up to 5 minutes. Within the same menu, an additional automatic pause feature could be activated so the simulation automatically pauses if the user fails to look at the moon for more than 15 seconds. Furthermore, the menu included an option to directly select the sequence to be played (e.g., dressing room, reception room, moon travel).

In addition, we implemented hidden controls to allow the VR operator to manage the experience more efficiently. The first hidden control reset the view when the joystick was pressed. The second enabled the VR operator to replay or skip to the next sequence by holding the joystick left or right while pressing the primary button (Y or B on the Meta controller), without needing to interact with the on-screen panels.

We paid special attention to ensuring that the language was accessible and child-friendly, and that the storyline effectively supported and reinforced MRI preparation procedures. The simulation offers multilingual support (French).

Figure 6 presents an overview of the designed VR application, and Appendix B summarizes all audio prompts.

Coding

In developing Mission Control, we focused on writing code that was robust, maintainable, and reusable. To achieve this goal, we structured each part of the system so it could function independently, reducing unnecessary connections between components (i.e., self-contained C# classes with minimal dependencies). We also used clear and consistent names for each element, making the code easier to read and modify (i.e., descriptive and unambiguous names for our variables, classes, and functions). These elements, adopted from software design principles (e.g., SOLID, DRY principles), made our code easier to understand, test, and reuse across different projects.

One of the first major changes we made to our Unity environment, compared to our earlier prototype, was switching to a different plugin for virtual reality. Although we initially used Meta XR (optimized for Meta headsets), we later migrated to OpenXR to support a broader range of devices and improve accessibility. We then started arranging our 3D models in Unity to visually reproduce the MRI environment of the Douglas Cerebral Imaging Centre, including the new rooms. Our next step focused on implementing key features discussed during the design phase—such as user interaction and system responses to user behaviour—through custom scripts (C#). The main programming scripts used in the simulation are described in Table 1. Figure 7 shows the different progression of events (i.e., sequences) in our VR environment.

The final code is available via the Open Science Framework (OSF; https://doi.org/10.17605/OSF.IO/NT4GX). Please note that 3D models—and therefore a significant portion of the visual environment—are not included due to licensing constraints.

Community and expert feedback during development

We received both internal and external support throughout the development of Mission Control. During the development phase, we tested the simulation with MRI specialists, designers, mental health researchers, and volunteer children from our research team. Their feedback helped us refine the instructions, improve the overall design, and fine-tune our features.

In addition to internal testing, we presented Mission Control at four public events in 2024 and 2025, which allowed us to gather valuable informal feedback beyond our research group, as presented in Table 2. Appendix C, Figure C2 provides an example of Mission Control being presented at one of these events.

In June 2024, we applied to the Meta Horizon Start Program, a developer support initiative launched by Meta. After being accepted in July 2024, we gained access to a community of VR developers through Discord (i.e., an online space for group discussions), where we benefited from peer advice and feedback throughout development. The Meta Horizon Start Program also allowed us to participate in the Meta Playtesting Event and receive feedback from ten adults, as shown in Table 2.

In all, four children provided unstructured feedback on Mission Control — two during the public presentation events and two children of our researchers during private sessions. All four reported enjoying the simulation, finding it easy to use, and said they would be happy to play it again.

Discussion

In this paper, we presented the design and development of Mission Control, a virtual reality preparation tool for pediatric MRI scans aimed at reducing distress and minimizing motion-related artifacts. The project was conceptualized by a multidisciplinary and multicultural team to ensure that the simulation is scientifically accurate, culturally sensitive, and inclusive. While these contributions highlight the promise of VR in this context, important considerations remain when implementing such tools with pediatric patients in an institutional setting. To guide future work, we outline key limitations below.

Limitations

Important limitations should be considered when using VR with pediatric patients. For instance, children suffering from seizures or significant visual impairments may not be cleared for VR use. Additionally, children who wear large glasses may face physical limitations with the headset. To address this, we plan to provide the same MRI-compatible glasses used during scanning, which fit comfortably inside the headset and match the child’s corrective lenses.

From a feasibility perspective, we have also identified logistical challenges. During the design and refinement stage, we considered offering families the possibility of renting a headset so that children could begin the simulation at home, allowing them to engage with the VR simulation autonomously in a familiar environment. This approach could potentially facilitate recruitment, particularly for neurodivergent children. However, home use would require access to a compatible VR headset (e.g., Meta, HTC, Valve, Pico, HP), which may not be readily available or affordable. Providing loaner headsets could mitigate this barrier but would involve additional costs and coordination, and questions about the procedure would not be addressed immediately by a professional. For these reasons, home use will not be included in the upcoming pilot study. Nonetheless, children and families who wish to explore the experience independently can download the application from our online repository (https://doi.org/10.17605/OSF.IO/NT4GX). As part of future work, we plan to make the application directly accessible via the Meta Store to facilitate broader dissemination and accessibility.

Institutional use also can require additional setup, such as a bed and a computer (if the VR operator wishes to monitor what participants see). Furthermore, staff members need basic training to operate the headset and troubleshoot technical issues. These challenges could be mitigated by providing clear instruction manuals or short training modules for VR operators.

A key advantage of our simulation is its potential to replace traditional mock MRI scanners, which are often large, costly, and difficult to install due to space constraints. For comparison, based on vendor quotes obtained by the Douglas Cerebral Imaging Centre, the price of a mock MRI scanner ranges from $24,000 to $58,000 USD (excluding accessories), depending on the features. This represents the equivalent cost of purchasing over 24 high-end virtual reality headsets (e.g., Meta Quest 3), making our solution portable, space-efficient, and more accessible for institutions with limited resources.

Recommendations

From a delivery standpoint, the various tests we conducted throughout the development led us to establish Figure 8, which illustrates the current preparation protocol we recommend for institutional use of Mission Control with a VR operator.

Additionally, to enhance the realistic sensation of being in a confined space similar to that of an MRI scanner, a replica of a head coil can be used when the participant lies down, as shown in Figure 9.

Future directions

As a next step, we will conduct a formal pilot study with children recruited through our research center to systematically evaluate the accessibility, feasibility, and gather preliminary efficacy data (e.g., head motion, reported emotional state) of our simulation for pediatric MRI preparation. Based on their medical condition and preference, children will be assigned to one of two preparation modalities: a traditional mock-scanner or the Mission Control VR preparation. We will compare children's eligibility to receive VR and their willingness to use it.

Across both the VR and mock-scanner modalities, we will use simple Yes/No questions and a Smileyometer scale to collect data on children's emotional states before and after preparation, their enjoyment of the preparation, and completion rates. Head motion will also be recorded during VR sessions. Reported emotional states will help us assess the tolerability of the VR simulation (including emotional or physical adverse effects). Subsequently, MRI session outcomes will also be recorded, including whether the full protocol was completed, session duration, and head motion quantification.

Prior to the pilot, our staff will receive training on how to operate the VR system, supported by a set of protocols to ensure consistent and safe use across sessions. The pilot will then allow us to evaluate the feasibility of the procedures, identify potential accessibility barriers, and detect early signals that the VR preparation may improve outcomes—such as reduced head motion and improvements in reported emotional state. Future research could extend this work by including neurodivergent children to evaluate the VR preparation in more diverse populations, thereby advancing equity and inclusivity in both research and clinical practice.

Additionally, future directions may involve expanding the application's capabilities, for instance, by incorporating additional languages through automatic translation and voice narration generated by text-to-speech (TTS) systems (Barrault et al., 2025) and the possibility of replicating other facilities and procedures. One promising solution would be to use 3D scanning and simple rendering tools to recreate MRI rooms that reflect each institution's layout (Verykokou & Ioannidis, 2023).

Conclusion

Virtual MRI experiences represent a promising tool to improve pediatric MRI procedures, helping children to be more effectively prepared. In this paper, we presented the development of Mission Control, a VR simulation for pediatric MRI experiences, carried out over a period of 18 months. By providing a detailed overview of our development process, we hope to support and inspire the creation of similar VR tools in the future. Initial informal feedback showed promising results, highlighting user engagement, a clear sense of immersion, and positive reactions. The collaborative nature of this project also makes it a valuable reference for teams interested in developing innovative solutions within research settings.

Acknowledgments

We would like to thank Antony Shruti for her contribution during the prototyping of Mission Control. We are also grateful to the organizers of the various events in which we participated, as well as to the Meta Horizon Start Program for their technical support during the development phase. Finally, we acknowledge all the researchers from our group who generously dedicated their time to playtesting the simulation.

Declarations

Funding

This research was undertaken thanks in part to funding from the Canada First Research Excellence Fund, awarded to the Healthy Brains, Healthy Lives initiative at McGill University, and by a gift from the Douglas Foundation.

Conflicts of interest/Competing interests

The authors declare that they have no conflict of interest or competing interests.

Ethics approval

Not applicable

Consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Code availability

The source code of our MRI VR simulation and the resulting application are openly accessible via the Open Science Framework: https://doi.org/10.17605/OSF.IO/NT4GX

Authors' contributions

Conceptualization: CD, AES, JS, NC, LS; **Methodology:** CD, AES, LS; **Coding Software-Prototype:** NC, CD; **Coding Software-Full version:** CD; **Voice Over**: JS, CD; **Writing - Original Draft:** CD, AES, LS, NC; **Writing - Review & Editing:** CD, AES, LS, NC; **Supervision:** ML; **Project Administration:** VV, ML; **Funding Acquisition:** ML

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Tables

Table 1

Main programming scripts (C#) used in Mission Control

Script	Description
EventSequence	Organises the actions that happen in VR in the form of events that unfold in sequential order (e.g., fade-in → audio → panel). Each event triggers the next upon completion. Supports looping sequences.
LocationTransition	Manages user positioning and orientation in VR, enabling smooth room transitions. A key feature is realignment, which repositions the user's head in front of a target. Earlier versions treated position and rotation separately, leading to misalignments in reclined poses. We replaced this with a unified method using multiple reference points and angle calculations, ensuring accurate alignment even in complex postures such as reclining or twisting.
TextDisplayer	Displays short text messages on screen, with support for both English and French. It allowed us to show messages on various panels throughout the experience (e.g., a panel that says "Welcome to Mission Control").
ManagedAudioSource	Plays audio in French or English based on language settings. It signals when an audio clip has started or finished to sync actions in the simulation with the narration.
HandleCollisionDetectionWithEvents	One of the most important aspects of immersive virtual environments is the ability to detect when the user comes into contact with virtual objects. This script extends Unity's default system to trigger specific actions when users interact with predefined virtual elements (e.g., touching the scrub suit triggers the action to put it on)."
HeadCollisionDetector	Unity's built-in system does not apply any physical response when the user's head collides with virtual walls in VR, allowing users to pass through them. HeadCollisionDetector prevents users from passing through walls by casting invisible rays from the head and applying a gentle opposing force when a collision is detected.
MenuPauser	Manages VR pauses by displaying a menu in front of the user. Can be triggered manually via controller or automatically during the moon trip sequence.
MoonMovement	This script controls the moon's motion, making it move closer, grow in size, and rotate slower over time to simulate approach.
ReticleController	Initializes and manages a fixation cross (i.e., reticle) that helps to guide the user's gaze.
HandleReticleCollision	Detects whether the fixation cross is properly aligned with the moon and triggers corresponding visual and auditory feedback.
CountdownAudioPlayer	Works in coordination with HandleReticleCollision to manage the timed delivery of audio cues—such as "Uh oh! Make sure you're flying towards the moon." or "We've passed the halfway point! Please continue holding the course; you're doing an amazing job."—to guide and encourage the user throughout the experience.

Script	Description
FeedbackLogger	Records changes in feedback states (i.e., time-stamped events indicating when the use's gaze was correctly or incorrectly aligned with the moon). The data is saved in a structured .json file at the end of each session.

Table 2

Public events where Mission Control was presented, and a summary of the feedback obtained

Event	User profiles	Feedback & Improvements to Mission Control
VR Expo at Shriners Hospitals for Children, March 2024	The hospital's child spokesperson	The user praised the realism of the MRI scanner's sounds
Douglas Research Day, June 2024	Four adults	Users described Mission Control as "engaging" and "realistic", with a strong sense of immersion inside the scanner, and realistic simulation of the associated anxiety To facilitate testing, we identified the need to add a live view for VR operators, provide more controls to VR operators (to help users navigate), limit controller actions (as first-time users pressed all buttons randomly), and include a pre-simulation tutorial to address the lack of VR basics understanding for first-time VR users Narration was hard to hear in noisy environments
VR Expo, March 2025	Two adults, Two children	We found that properly configuring the Meta Quest's spatial boundary was crucial, with Stationary mode providing more accurate tracking than Room-Scale. We also found it necessary to restart the application to mirror the headset view to the PC (i.e., the scrcpy app) between participants, as extended idle time could disrupt screen casting.
Meta Playtesting Event, April 2025	Ten adults from the Meta Horizon Start Program	Users completed feedback surveys showed an average score of 7.1/10 for overall experience and 7.5/10 for user experience. Most users appreciated the realistic portrayal of the MRI process, and their input helped us address various technical and design issues.

Figures

Figure 1

Overview of the Douglas Cerebral Imaging Center's lunar exploration theme using decorative posters, thematic MRI scan cover, and child-friendly motifs

Figure 2

Flowchart outlining the development process of Mission Control

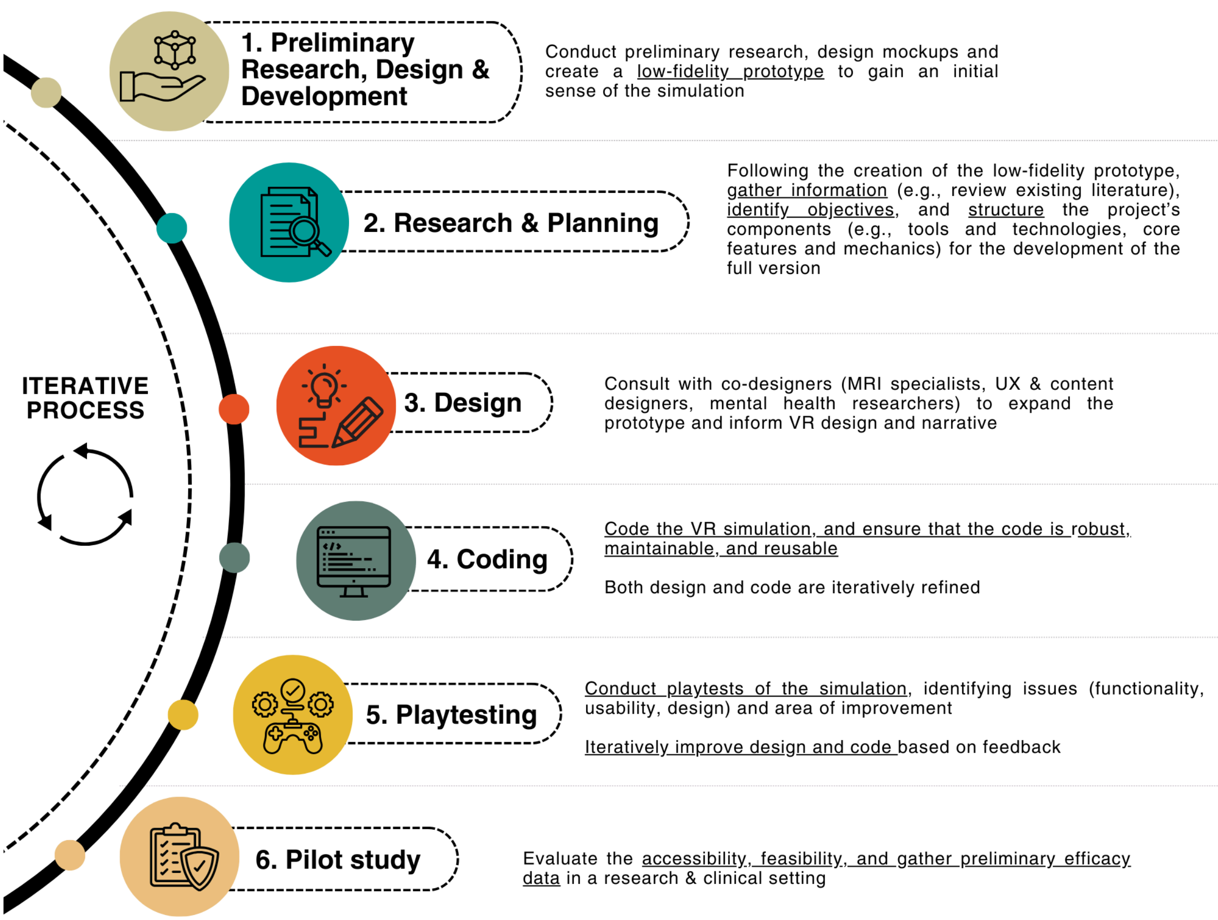
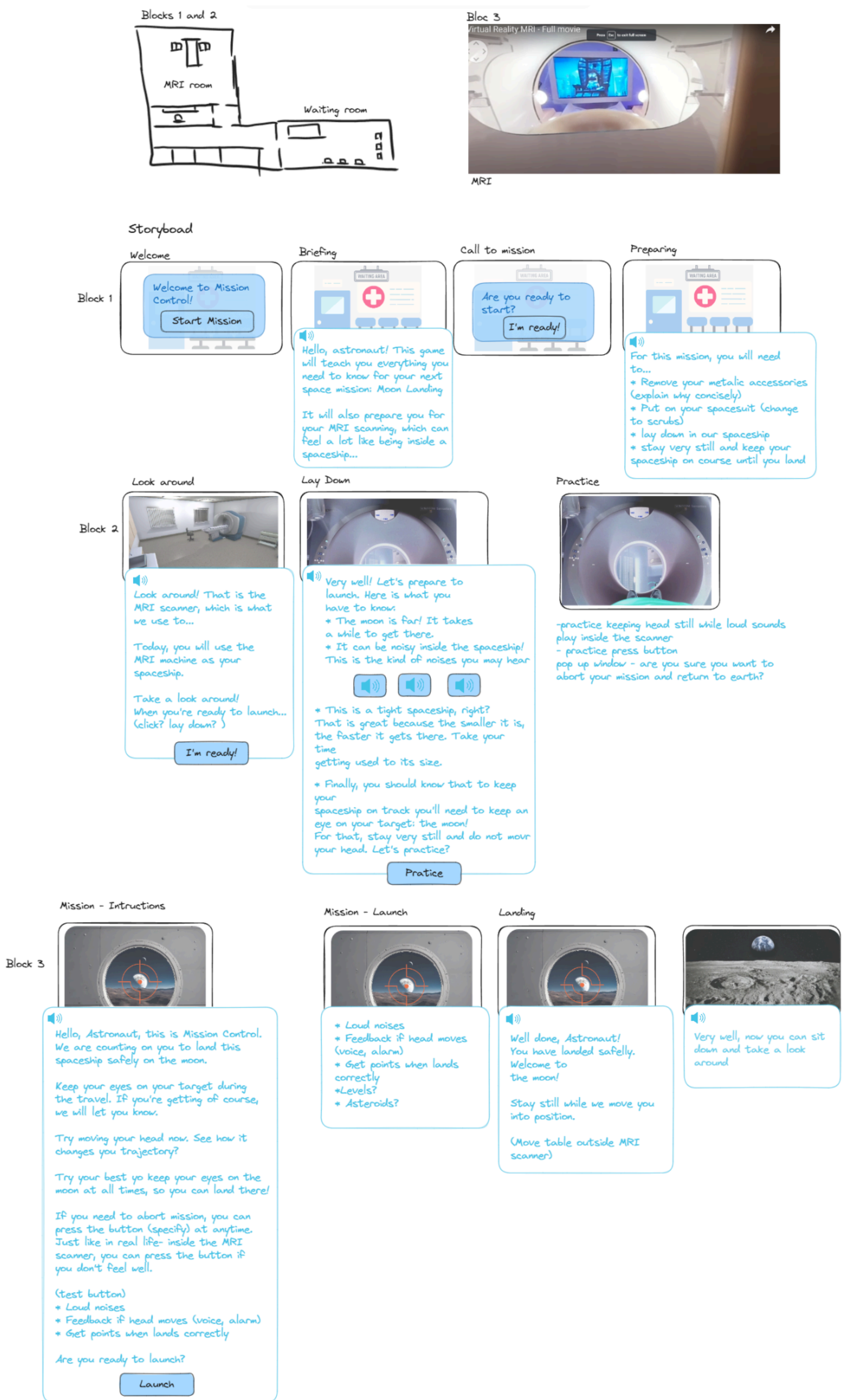


Figure 3

Initial mock-up used for the design of the prototype of Mission Control



Note. Three key blocks were originally envisioned for this prototype: 1) a waiting room for explanation, briefing, and preparation; 2) an MRI room to help children become familiar with the scanning environment; and 3) the interior of the virtual MRI scanner, where children embark on a narrative-driven journey to the moon.

Figure 4

Overview of Mission Control prototype

Note. The prototype consisted of three main components: 1) a briefing room featuring a “call to mission” scene and a short sequence guiding the participant to remove accessories; 2) the MRI room; 3) and the interior of the virtual scanner, where a video of a trip to the Moon was displayed, accompanied by a voice encouraging the participant to maintain focus on it.

Figure 5

MRI room at the Douglas Cerebral Imaging Centre and its 3D recreation for the full version of Mission Control

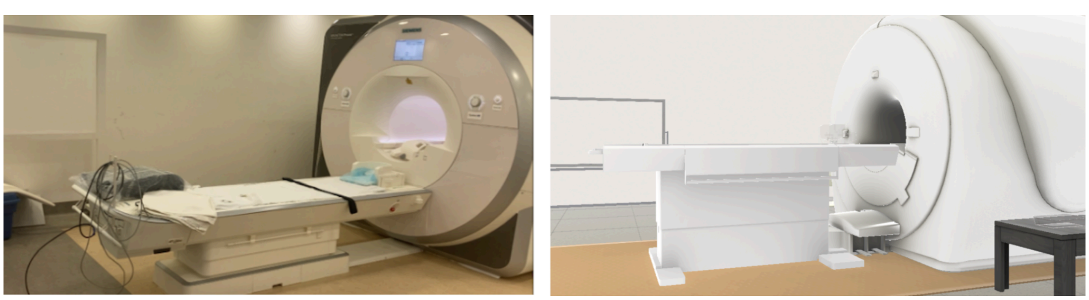


Figure 6

Overview of the full version of Mission Control

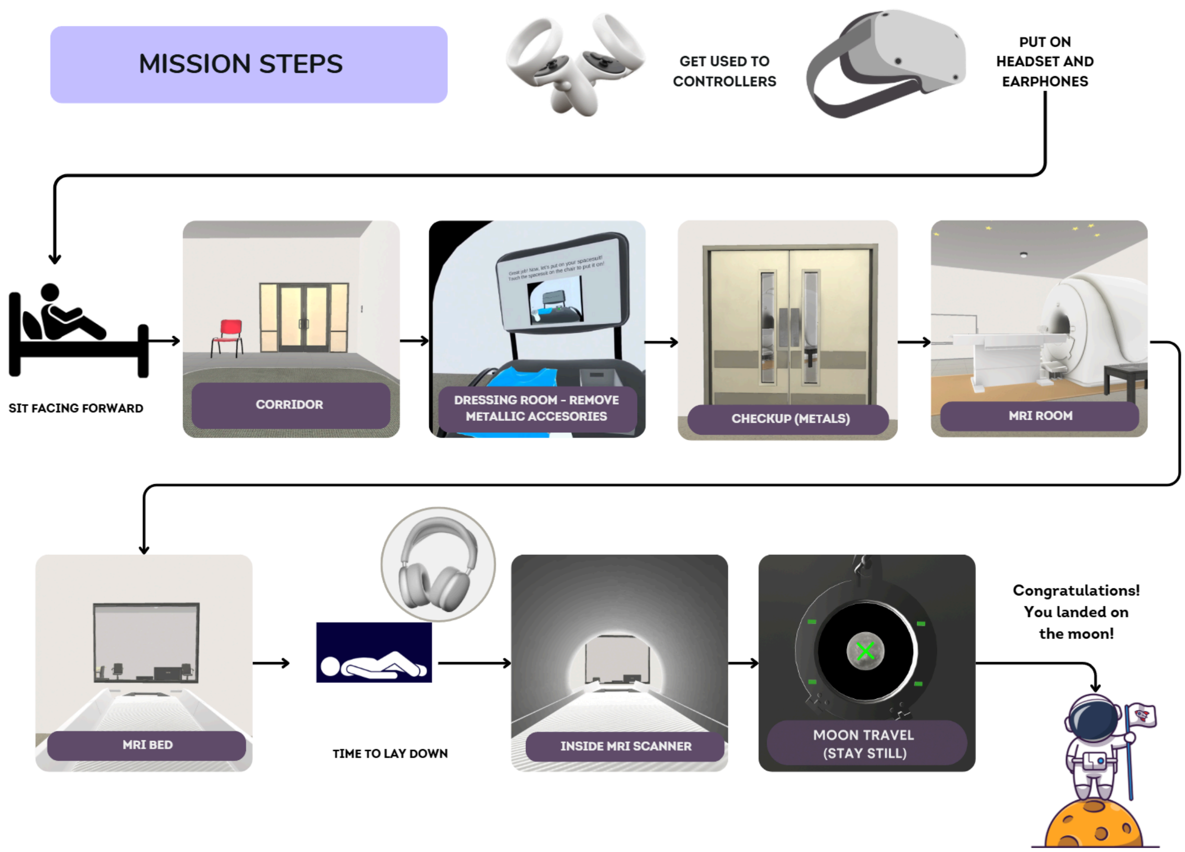


Figure 7

Overview of Mission Control sequences

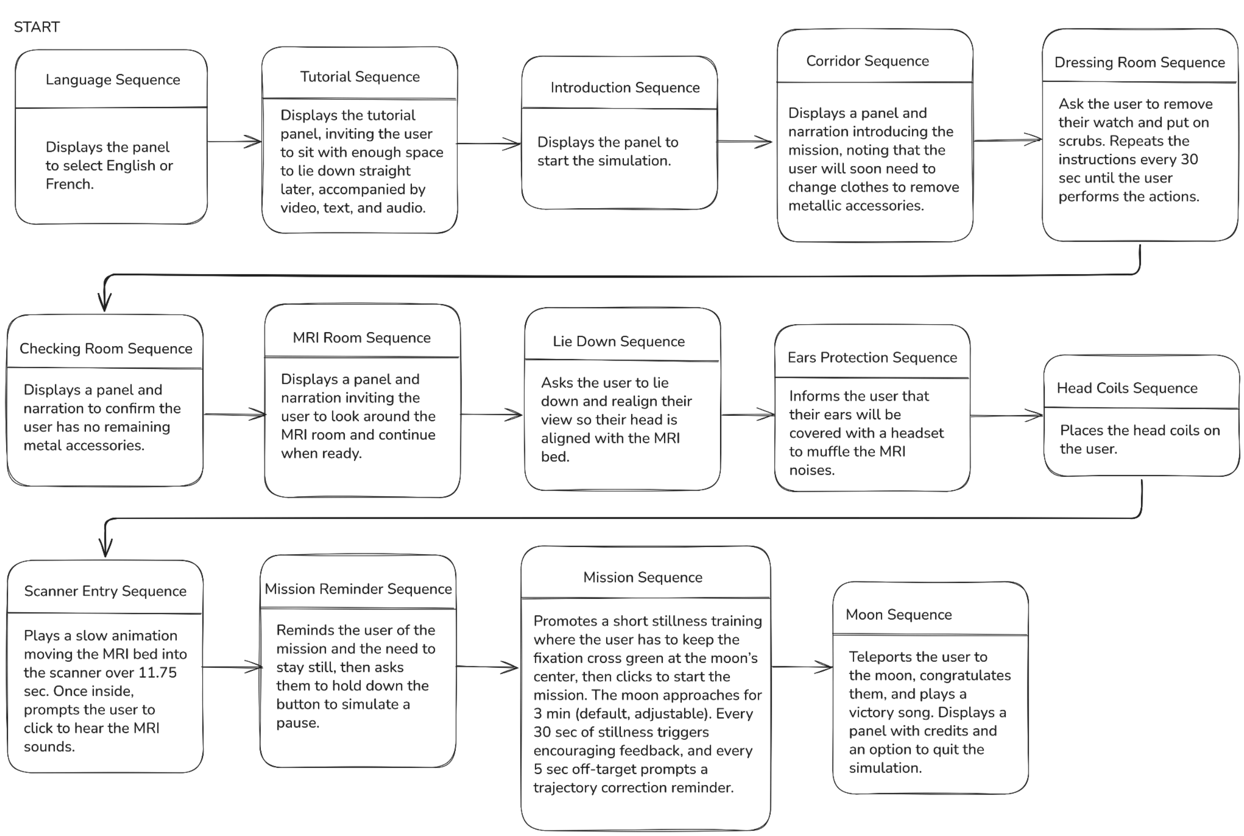
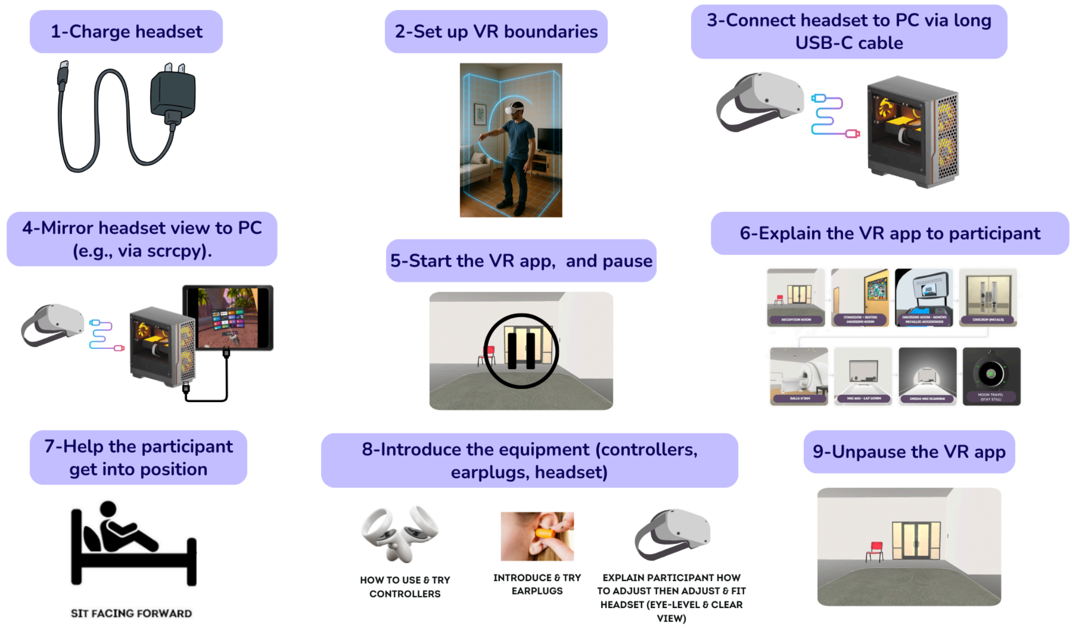


Figure 8

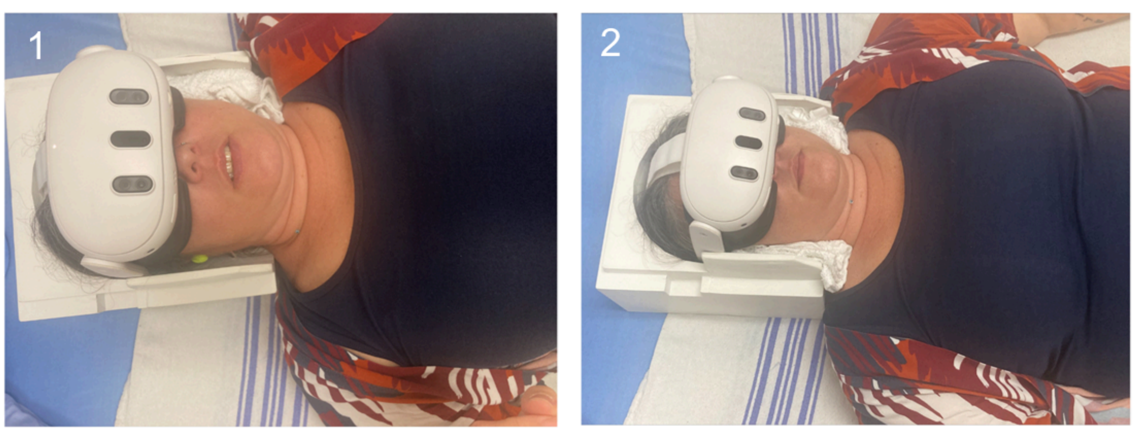
Recommended VR preparation protocol for institutional use with VR operator assistance



Note. Before the session begins, VR spatial boundaries should be carefully drawn. The VR operator should use software (such as scrcpy) to mirror the headset view onto a PC before starting the VR application. Participants should first be seated in a predefined position from which they can later lie down straight—without needing to turn—to simulate the MRI posture. The VR operator should have access to one controller to assist if needed and should remain within the defined boundary throughout the session to ensure proper tracking and interaction.

Figure 9

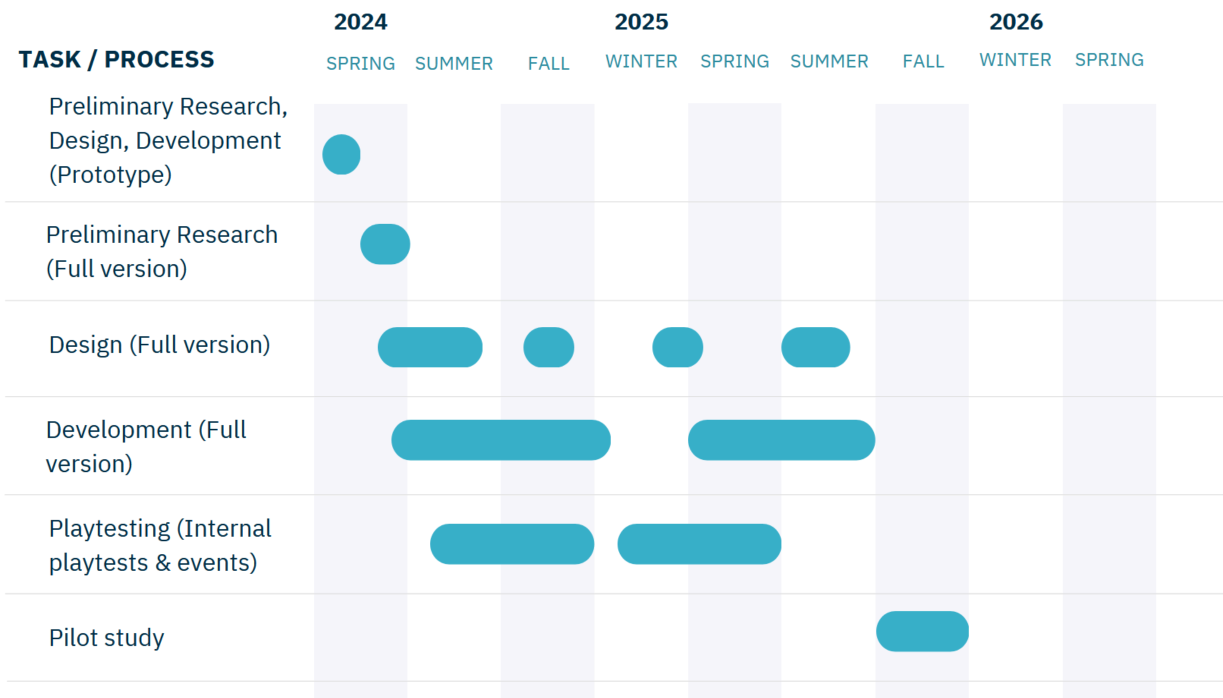
Example of a user lying down with a replica MRI head coil



Note. To adapt the setup for children, pads or towels can be used to ensure a proper fit around the head. Earplugs (1) can be inserted before placing the towels (2) to provide an experience closer to a real MRI.

Appendix A

Project timeline for Mission Control (Gantt Chart)



Appendix B

Moon trip: summary of audio prompts

Type	Description
Positive Feedback (30 sec of stillness)	You’re off to a great start. If you keep this up, we’ll get to the moon in no time! Wow! I know we just started but you make this look easy. Looks like we picked the right astronaut for the job. You’re a real pro at this. Way to go astronaut! We’re almost halfway there. We’ve passed the halfway point! Please continue holding the course; you’re doing an amazing job. Keep up the great work! Remember that you can take a break if you need to. Oh wow, can you see how close we are to the moon? Great work, astronaut! Keep focusing on the moon just like you’re doing! I know this is tough, but you’re almost there! You’re doing an amazing job staying still. See all those craters on the surface of the moon? They all have their own names. Maybe we can even name one after you!
Reminder (5 sec off-target)	Remember, turn your face towards the moon to steer the rocket ship. You don’t want to miss the moon and fly off into space! Remember, turn your face and look at the moon to fly towards it. You know you’re doing it right when the cross is over the moon and turns green. Uh oh! Make sure you’re flying towards the moon. Careful, there Astronaut, you might miss the moon. You’re going to miss the moon! Try your best to keep your eyes on the target. Just make sure you keep looking at the moon. Check your course, Astronaut! Are you looking at the moon?
Fixed (trajectory corrected for at least 5 sec)	Perfect, just like that! Great job!
Automatic Pause (appears if enabled and after 15 s off-target)	It looks like you haven’t been looking at the moon for a while, so we’re pausing the experience. Take a moment to refocus before continuing your mission. This is your second pause—you’ve lost focus again. Try to keep your eyes on the moon, so the cross is always green!

Type	Description
	Hey Astronaut! It looks like you're having trouble keeping your trajectory. Would you like to hear the instructions again and restart your journey, or switch to autopilot to complete your mission?
Landing	Fantastic job, Astronaut! You've successfully landed on the moon! Stay still while we move you into your lunar exploration position.

Appendix C

Recognition on social media

The following social media posts highlight recognition of our application, which earned first place during the NeuroVR Hackathon 2024, organized by McGillXR.

Figure C1

Screenshot of an Instagram post announcing first place for our application (April 2024).

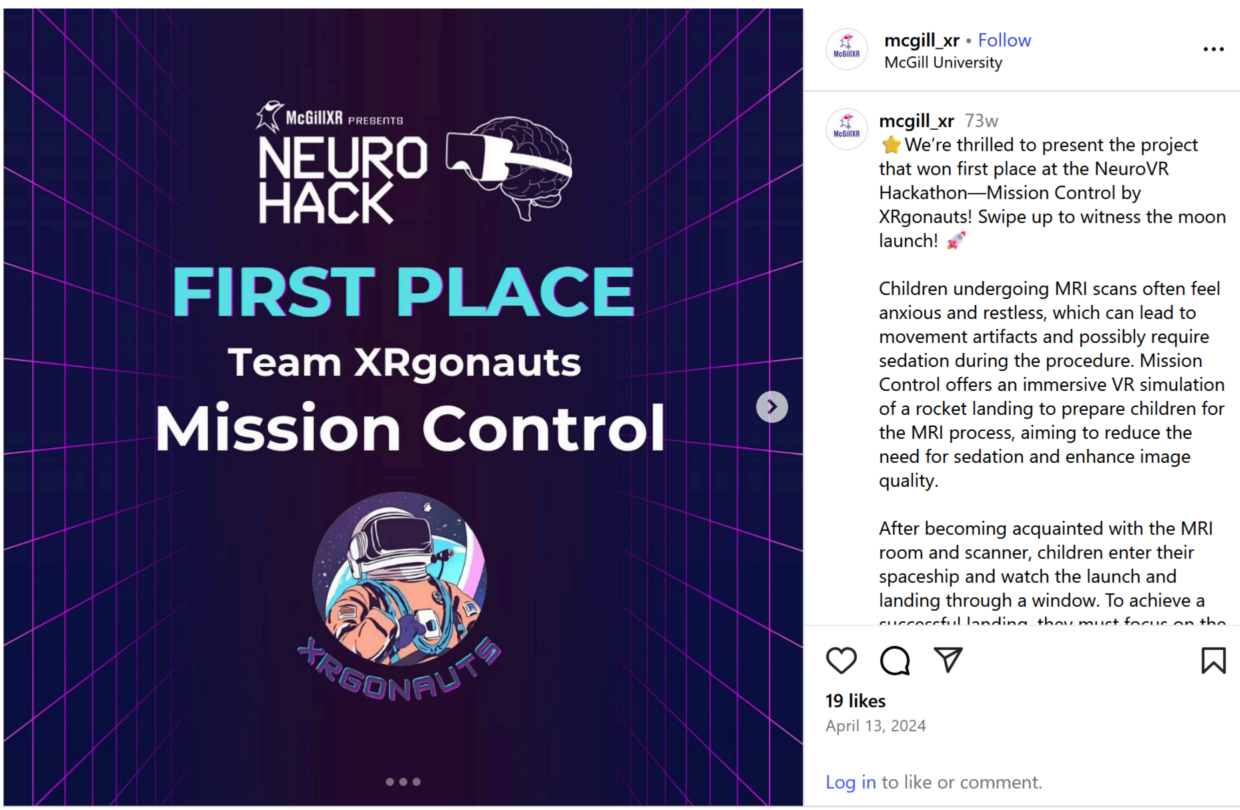


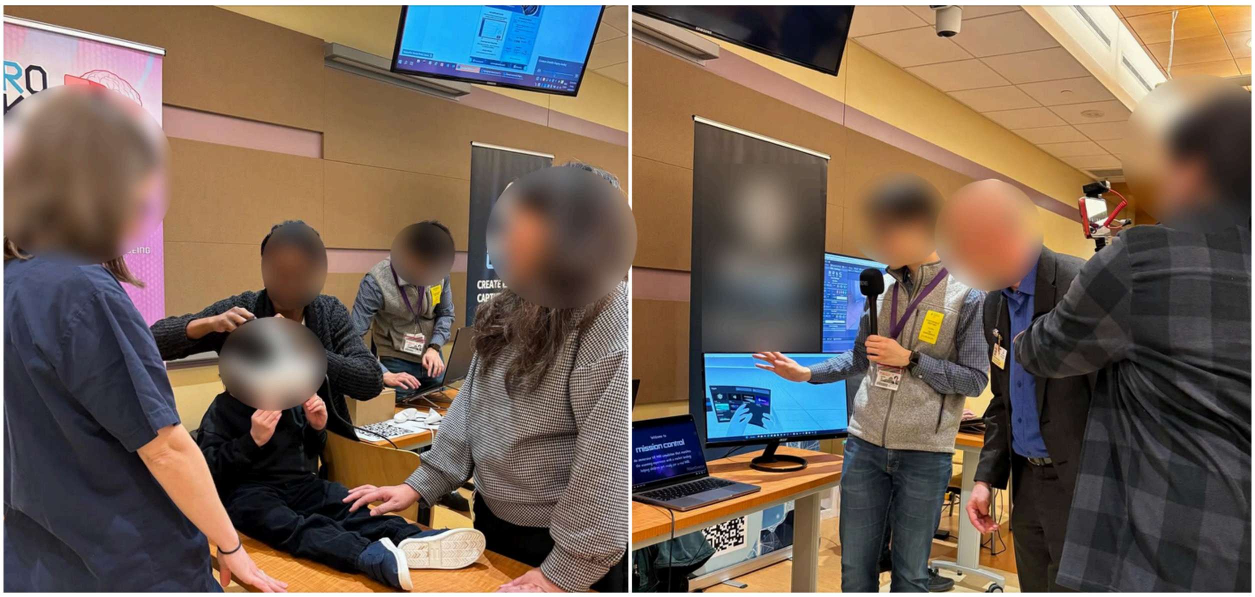
Figure C2

Screenshot of a Facebook post, highlighting that Mission Control was presented at Shriners Hospitals for Children for VR EXPO 2024 (May 2024).

McGill XR is at **Shriners Hospitals for Children - Canada**.
May 5, 2024 · Montreal ·

Last week, we had the privilege of participating in the Virtual Reality Workshop in Child Health Setting at Shriners Hospital. During the event, we showcased our award-winning project from the NeuroVR Hackathon – Mission Control. This immersive VR simulation of a rocket landing is designed to alleviate anxiety and restlessness for children undergoing MRI scans.

A heartfelt thank you to everyone who showed interest in our club and to the organizers of the event for their support!



Note. Faces were blurred to protect participants' privacy.