Re-design of an educational scanner to prepare children for an MRI or CT scan

Privender Saini
Digital Engagement, Behavior & Cognition
Philips Research
Eindhoven, The Netherlands
privender.saini@philips.com

Annerieke Heuvelink
Digital Engagement, Behavior & Cognition
Philips Research
Eindhoven, The Netherlands
annerieke.heuvelink@philips.com

Özgür Taşar
Product Design
Philips Experience Design
Eindhoven, The Netherlands
ozgur.tasar@philips.com

Elizabeth van Vorstenbosch-Lynn
Clinical Application
Philips MR
Best, The Netherlands
elizabeth.van.vorstenbosch-lynn@philips.com

Sanae van de Vleuten-Chraibi
Ambient Experience
Philips MR
Best, The Netherlands
sanae.vander.vleuten-chraibi@philips.com

Sanne Nauts
Digital Engagement, Behavior & Cognition
Philips Research
Eindhoven, The Netherlands
sanne.nauts@philips.com

2023 IEEE 11th International Conference on Serious Games and Applications for Health (SeGAH) | 979-8-3503-4607-7/23/$31.00 ©2023 IEEE | DOI: 10.1109/SEGAH57547.2023.10253811

***Abstract*— The Kitten Scanner is an educational scanner that can be used to playfully prepare children for an MRI or CT scan. The current paper describes a re-design of the Kitten Scanner to increase its educational value and prepare a diverse group of patients for a diverse range of scan types. Learning goals were created that are applicable to both MRI and CT. Based on these learning goals, storylines were developed for 3 different characters, with each character showcasing a different scan and emotional response.**

Keywords—Patient Preparation, Pediatric Radiology, MRI, CT, Children, Patient Experience

I. Introduction

Undergoing an MRI or CT scan can be an anxiety-provoking experience for children. Magnetic Resonance Imaging (MRI) and Computed Axial Tomography (CAT, or CT for short) require that a young child lies down on a table that moves into a large, donut-shaped machine. During the scan, children hear odd, jarring noises, and have to lie very still, as even minor motion can reduce the diagnostic quality of the scan. The current paper describes the background and design journey for a small-scale educational scanner that can be used to prepare children for their scan. The goal of this educational tool (the Kitten Scanner) is to create a positive scan experience for children and their families, while enabling healthcare providers to get the high-quality images they need for their diagnosis.

A. Approaches to scanning pediatric patients

Many hospitals scan young children using anesthesia or sedation, as this facilitates an efficient, predictable workflow with high-quality diagnostic images. However, compared to scanning children awake, a scan with anesthesia carries higher costs, is associated with more time spent in the hospital [1] and can lead to post-scan irritability in children [2]. Moreover, there is an ongoing scientific debate about the safety of using anesthetic drugs in young children, with some studies suggesting that repeated, prolonged anesthesia exposure may negatively affect long-term neuro-developmental outcomes in children (for reviews, see [3][4][5]). As such, radiology departments increasingly attempt to scan children awake, using various approaches to prepare children and create a child-friendly atmosphere. Approaches that can be used to prepare children include using gamified apps [6][7], Virtual Reality (VR; [8][9][10]), educational videos ([11][12][13][14]), therapy dogs [15] and play therapy/preparation by healthcare providers or Child Life specialists [16] [17]; for an overview of different approaches, see [18][19][20]). Several preparation programs that reduce the need for sedation/anesthesia have shown to be cost-effective [9][21][22]. Many of these approaches use gamification approaches such as using virtual companions. Storytelling, and rewards.

B. Preparing patients with an educational scanner

Studies suggest that preparing children for their MRI using a mock scanner or small-scale educational scanner may enable awake scanning of pediatric patients [21][23][24][25]. In the early 2000s, Philips introduced the Kitten Scanner, an educational small-scale scanner that can be used in the hospital to playfully prepare children for an MRI or CT scan. The user flow is depicted in Fig. 1. A child chooses a character doll from the character board, puts it on the table of the Kitten Scanner, and inserts the character into the Kitten Scanner by pushing the table into the scanner. The mock scanning is triggered when the character doll (embedding an RFID tag) is placed in the mock scanner and an animated story is initiated on the screen that is specific to the character. A study in which children (aged 4 to 14) were prepared for their MRI using the Kitten Scanner showed a 30% reduction

Fig. 1. User flow of Kitten Scanner

in need for anesthesia [24]. In another study, the Kitten Scanner was part of an extensive, multi-faceted Children-Centered Care (CCC) program for children aged 4 to 6, that included an app, a trained pediatric team, a child-friendly imaging room and children's lounge with the Kitten Scanner. In this study, the anesthesia rate was significantly lower in the CCC-group (5%) compared to the control group (57%), while image quality was identical for both groups [21]. Taken together, these studies suggest that educational scanners may effectively support anesthesia-free MRI in young children, especially when supplemented with additional preparation and guidance (such as an app, child friendly imaging room, and hospital staff trained to support pediatric patients).

C. *Embodied Learning*

A distinct strength of educational small-scale scanners is that they enable active learning, in which children learn through activities instead of by passively listening to what they need to know. Active learning has been shown to be more effective than traditional lecturing [26]. One of the core reasons Serious Games are so effective as educational tools is because of this activating, engaging component.

Next to the digital stories, the Kitten Scanner also has important hardware components: the Kitten Scanner itself, and the physical character dolls. These are tangible objects providing opportunities for tactile play and tangible interaction, which constitutes a form of embodied learning. This learning approach capitalizes on the physicality of the educational scanners, which enable sensory-motor exploration. The child can see, smell, touch, and manipulate the Kitten Scanner and character dolls. Learning occurs because sensory processes stimulate cognitive processes: touch, vision, and sounds stimulate and facilitate thought [27][28][29]. Through their senses, people (i.e., children) create multisensory representations of the context and environment as they interact with it and can mentally access these representations when they imagine the same context or object [30]. Recruitment of the motor system (walking around the Kitten Scanner, holding and manipulating the character dolls) supports cognitive processes when learning something new [31][32]. Thus, pushing a character doll into the Kitten Scanner can help children understand that the scanner table can move in and out of the bore, that the scanner will not touch them, that there are no monsters behind the bore and that the character doll comes out the same as it went into the scanner.

II. Re-Design of the Kitten Scanner

A. *Rationale behind re-designing the Kitten Scanner*

Although educational scanners enable active, embodied learning, the educational value of the digital content of the old Kitten Scanner was limited. The primary reason to re-design the Kitten Scanner was thus to improve its educational value by further capitalizing on the strength of educational scanners (enabling active and embodied learning) by creating more educational, engaging digital content. This digital content can help children grasp concepts that are important for an upcoming scan but are not captured in the old Kitten Scanner. An example is familiarizing children with the sound of a scan, which can be odd, jarring, and in the case of an MRI scan, very loud (ranging 82–138 dB [33]).

A second goal of the re-design was to embed the Kitten Scanner in a broader solution to prepare and guide Pediatric Patients (the Pediatric Coaching solution; see Fig. 2), including a gamified app to prepare children at home (called Scan Buddy), and a child-friendly imaging room with positive distraction and guidance during the scan. The Kitten Scanner can be used as a stand-alone preparation tool, or as part of a multi-faceted solution, depending on the needs of a hospital.

Fig. 2. Scan Buddy app (left) - extensive preparation at home playing with the app, days prior to the scan. Kitten Scanner (middle) - preparation on-site, moments before the scan. In-bore coaching (right) - child-friendly scanning room and guidance during the scan.

A third goal was to adapt the physical design of the Kitten Scanner to better support children who need to undergo an MRI scan. While the old Kitten Scanner was modelled after a CAT scanner (see Fig. 3), an attempt was made to redesign the Kitten Scanner to ensure similarity to both CT and MRI scanners.

Fig. 3. Original Kitten Scanner (left) and the full-size CAT scanner to which it was modelled (right).

B. *Team composition*

As recommended by [34], we deployed a multidisciplinary team for re-designing the scanner as a health education tool containing serious gaming-elements. This team to re-design the Kitten Scanner included psychologists, designers, serious gaming experts, as well as content and domain specialists.

C. *Design challenge*

Many hospitals have a radiology preparation room or waiting room that can be used to prepare patients for either an MRI or a CT scan. There are large differences between pediatric patients in terms of age, gender, emotional response to the scan, previous scan experience, and the type of scan they need (MRI vs CT; different anatomies; with and without contrast, etc.). If a Kitten Scanner is placed in a waiting room or children's lounge, it is likely that multiple children interact with it simultaneously. For example, an 8-year-old waiting for his knee CT may be using the Kitten Scanner together with a 4-year-old waiting for her abdominal MRI, while a 6-year-old waiting for her head MRI watches them play.

We attempted to maximize the Kitten Scanner's educational value, while ensuring that it teaches the right things in an engaging and motivating way to a diverse group of patients who come to the hospital for a diverse range of potential scan types. There is friction between these two goals: maximizing educational value for a single patient may come at the expense of the number of patients that can benefit from interacting with the Kitten Scanner. We tried to resolve this apparent contradiction by primarily focusing on those elements of the scan experience that apply to all patients and scans and emphasizing those in the storylines of all animated stories. However, to show diversity in scan procedures and patient's emotional responses, we introduced three different characters, with their own storylines and experience.

D. *Physical design*

With the physical design of the Kitten Scanner, we highlighted those elements that all scanners have in common (such as the scanning tunnel, called the bore, and a moving patient table). Many MRI scanners have a circular shape with a relatively long bore (typically 1.5m to 2m), while CT scanners can be circular or rectangular in shape and have a much shorter bore length (typically 0.8m to 1m). The shape of the Kitten Scanner is an intermediate between a square and a circle (called a *squircle*, see Fig. 4) with an intermediate bore length. As such, the Kitten Scanner is created to be similar to an MRI scanner and a CT scanner.

Fig. 4. A CT scanner (square), an MRI scanner (round), and a Kitten Scanner (squircle).

E. *Framework and learning goals*

We used the FIT-for-MRI framework [7] as a foundation for the learning modes that are used in the Kitten Scanner. FIT stands for Familiarize, Inform and Train, and is built on the premise that learning can take on different modes: it can be explicit (*Inform:* children can learn through explicit instruction), implicit (*Familiarize*: children can learn through observation or exposure and habituation/desensitization) or procedural (*Train:* children can learn through training and practicing, especially for the acquisition of a new skill).

While the FIT-framework describes different modes of learning (*how* children can learn), the content of learning (*what* they should learn) is captured in learning goals. Many existing approaches (such as educational videos or brochures) use only one learning mode: explicit instruction (*Inform*). However, for many learning goals, it can be effective to convey learning through multiple learning modes. For example, telling children about sound ("the scanner makes odd sounds") can be helpful, but it will become even more effective if children are familiarized and habituated to the sound by letting children hear the sound in a fun, engaging animation. Thus, it is important to consider *what* children need to learn for a scan (learning goals), while considering *how* to best convey every learning goal (learning modes).

F. *Development of learning goals for the Kitten Scanner*

Since the Kitten Scanner should prepare patients that need either an MRI or a CT scan, we needed a set of learning goals that apply to *both* MRI and CT. To arrive at this set of learning goals, we started with the learning goals for MRI. For a description of how these learning goals were constructed, please consult [22]. Next, we defined an initial list of potential learning goals for pediatric patients for an awake CT scan by consulting scientific literature, videos of young patients undergoing a CT scan, patient preparation videos, hospital brochures and other available material. Next, we asked two CT experts and two Child Life Specialists to provide feedback to the list of learning goals, and to indicate which learning goals were most important. Based on these discussions, one new learning goal was identified that we did not previously have for MRI or CT: *coping techniques*, which refers to teaching children strategies to manage their emotional state (such as anxiety or boredom). It is a goal that is especially relevant for the context of the Kitten Scanner, given that children interact with the Kitten Scanner in the hospital, typically just before they have their scan. Finally, the resulting list of learning goals for CT was compared to the learning goals for MRI, and we selected only those learning goals that applied to both modalities. Despite the differences between MRI and CT, there was a lot of overlap between learning goals for both modalities, and the most important learning goals were things that both modalities had in common. The result is the list of 6 learning goals that are relevant for both MRI and CT (TABLE 1).

TABLE 1. LEARNING GOALS FOR KITTEN SCANNER

Learning Goals Kitten Scanner	
1.	Understanding the procedure
2.	Exposure to scan (MRI and CT) sounds
3.	Deducing the size of the scanner
4.	Deducing that the scan takes time
5.	Importance of (practicing) lying still
6.	Coping techniques

G. *Stories and characters*

Given that some children will have limited time to interact with the Kitten Scanner before being called in for their scan appointment, the educational stories needed to be short. Storylines were designed to take 1 to 2 minutes to maintain patients' attention and ensure that patients can finish the story before they are called in for their scan. The stories are centered around relatable characters (Fig. 5). The three characters have different personalities, backstories, and represent different 'patients' with different strengths and concerns. All three stories focused on the Kitten Scanner learning goals and used multiple modes of learning.

Fig. 5. Ollie (elephant), Doris (chick) and Chris (crocodile)

H. Stories and characters

Given that some children will have limited time to interact with the Kitten Scanner before being called in for their scan appointment, the educational stories needed to be short. Storylines were designed to take 1 to 2 minutes to maintain patients' attention and ensure that patients can finish the story before they are called in for their scan. The stories are centered around relatable characters (Fig. 5). The three characters have different personalities, backstories, and represent different 'patients' with different strengths and concerns. All three stories focused on the Kitten Scanner learning goals and used multiple modes of learning.

Given the inherent complexity of MRI versus CT (longer scan time, louder noises) two stories are slightly more focused on preparing patients for an MRI scan (exemplified by presence of MRI sounds and MRI appropriate back stories) and one on CT (CT sounds, and CT appropriate backstory). However, all stories are written and designed such that they could support either scan modality.

The stories are all set up in the same way. A character is introduced by name and the part of the body that needs to be scanned. Next, you see the character go into the scanner and a backstory starts of why the character needs a scan, i.e., explaining what happened to the character. The backstories are designed to appeal to a pediatric population with the core motivational driver of gamification being empowering the patient and instilling confidence. After the backstory, we see the character having the scan, a progress bar, and a scan which is slowly exposed in line with the progress bar. Then, the scan-related struggle is presented, and the main learning goal addressed, taking into account the learning framework and pediatric population.

The story ends when the scan is completed successfully and the character hops off the table. Emphasis is placed on the scan and a summary of the learning goal is presented concurrently to link success with observed behavior, to display a sense of accomplishment. Finally, the character is praised for doing a good job, and rewarded a certificate of MRI completion.

a) Ollie the Elephant - Backstory

Ollie was playing in her room. She had the music on and was having a great time dancing. But she went a little too far when she started dancing on a chair: she fell off and hurt her head. Now she needs to have a picture taken of the inside of her head, so the doctor can take a good look (Fig. 6). Head scans are very common in pediatric patients and are required for a variety of different reasons, including a head injury from a fall.

Fig. 6. Ollie's story

Main learning goals: lying still and coping techniques. Ollie is a little goofy, and she is not very good at lying still. In fact, most children are not very good at lying still, even if there is no stressful situation like undergoing a scan. The story emphasizes that *it is important to lie still* while having your picture taken. Ollie found a really good way to calm herself and keep still (coping strategy): she *pretends that she is an astronaut* floating gently through space.

b) Chris the Crocodile - Backstory

Chris is out in the streets, riding his skateboard and doing tricks. He is very good at this. But accidents happen, even to the most skilled rider. We see Chris doing a trick and falling off his board (Fig. 7). He needs to have a picture taken of his knee. Orthopedic scans are also quite common in children, due to accidents such as Chris', as well as developmental issues.

Fig. 7. Chris' story

Main learning goals: coping techniques. Chris does not know what to expect from the scan. This is a non-leading way of saying that Chris is anxious. We expect many children in the waiting room to be *anxious or worried* to some extent about having a scan. To help Chris with his anxiety, the story shows other children who have already had a scan give Chris *tips about how to calm his nerves*. One of the children mentions that he was *not alone in the room*, and it was nice to have a *family member there*. Another child mentions that she *pretends* that she is an astronaut and floats in space. And that if she still gets a little nervous, she *takes a few deep breaths*.

c) Doris the Chick - Backstory

Doris' backstory is a little less clear-cut. Doris did not get into an accident like the other two characters. We see Doris having a belly ache and needing a scan with special medicine (contrast). Doris is a seasoned patient who has had many scans. She is a role model displaying tips and techniques to cope with lying still in a bore (Fig. 8). She and her story are designed to appeal to first-scan children (needing to have a scan without a clear cause like a fall) as well as repeat-scan children. To repeat-scan children, who are dealing with long-term illness like cancer, she might be recognized as a long-term patient (no hair, headband of hope) to make identification with her more likely.

Fig. 8. Doris' story

Main learning goals: lying still, sound exposure, coping techniques. Doris *knows exactly what to do* when it comes to having her picture taken. She knows that she needs to lie still, and that she needs to keep herself busy because it can take a long time, and she knows how she can engage and distract herself from the scanning noise. In the story, we show what Doris does while she is in the scanner. For example, to *distract herself* from the (MRI) sounds, she *pretends that she is in a loud rocket or playing the drums*. To *demystify the contrast fluid*, Doris pretends that the '*special medicine' gives her superpowers*. The learning goals support the child who has never had a scan but also confirms to the child who is not new to this that it is mostly about keeping yourself occupied while you are being scanned.

d) Overall story learning and gamification elements

The main learning goals are centered around coping strategies, lying still and scanner noise. The other learning goals are addressed as part of the story and visual elements, as well as reinforced through gamification mechanism.

Understanding the procedure. A short version of the procedure is part of every story: the character hops onto the scan table and lies down, either head-first or feet-first. We show all characters doing this calmly and without fear. Then the scan starts, as well as the scan noises. When the scan is done, the character slides out, gets off the table, and is ready to go. The main gamification elements consist of the character modeling appropriate scan behaviors.

Coping techniques. This learning goal is an important one, as it provides insight into what patients could potentially do if their anxiety increases while in the bore. Three techniques are displayed by the characters: Ollie imagines a calming scenario of floating though space to get her anxiety under control. Chris gets tips from other kids to focus on the fact that he is not alone while having a scan, and that he can imagine something that calms him. Finally, Doris' advice can help an anxious first-timer to manage anxiety, but also appeal to the repeaters as they can be seen as things to do to pass the time or numb the sounds. Doris has different fun scenarios going through her head, like pretending that she is playing the drums, or is in a rocket to normalize the loud sounds. She pretends that the contrast agent gives her superpowers. By presenting different relatable characters presenting different needs and coping, we provide the child with inspiration of how to handle things when in the bore. We employed gamification motivations around empowerment and accomplishments to engage the patient.

Exposure to scan (MRI and CT) sounds. Although this goal is explicitly addressed in Doris' story, MRI or CT sounds are heard in all the scanning scenes. Specifically, MRI sounds are present in the stories of Ollie and Doris, and CT sounds are present in Chris' story.

Deducing the size of the scanner. The fact that the Kitten Scanner is a tangible object and tangible characters can be put on the table and in the Kitten Scanner, helps children deduce the size of the scanner. The same is the case in the story elements where the proportions of scanner and character are appropriate. The characters fit very comfortably in the scanner, with some room to wiggle, but they cannot easily get up and crawl out. The scanner-to-character ratio is appropriate.

Deducing that the scan takes time. Unfortunately, we cannot simulate an accurate scan-time due to the fact that the Kitten Scanner story needs to be short enough to be played and finished in the waiting room. However, with the sequence of events (character goes in the bore, backstory is played, progress bar, picture exposed bit by bit) we aim to convey that a picture taken by an MRI or CT scanner is not as quick as a picture taken with a smartphone. The progress bar and scan picture slowly being exposed are gamification elements we used to keep patients engaged in the story to show a lapse in time.

Importance of (practicing) lying still. This is addressed explicitly in two stories but is also displayed by all three characters in the scanning scenes. We see all three characters (getting) on the scan table, looking calm and relaxed. In addition, as part of Ollie's story, she can be seen practicing lying still at home (important for first-timers). For Doris, the narrator mentions that she knows exactly what she needs to do, including lying still. Gamification elements are behaviors modeled by relatable characters in a story of empowerment.

III. CONCLUSIONS

The Kitten Scanner is an educational scanner that aims to prepare children for an MRI scan or CT scan. It enables active, playful, embodied learning. However, the educational value of the digital content in the old Kitten Scanner was not optimized. Therefore, the Kitten Scanner was re-designed to increase the educational value of the digital content; embed it in a multi-faceted solution; and to make it look more similar to both a CT and an MRI scanner.

The Kitten Scanner can be used to prepare patients with a variety of needs and characteristics for various scan types, and thus our goal was to maximize the educational value of the Kitten Scanner. The friction between these two goals (high educational value and applicability to a wide range of patients) was resolved by focusing on learning goals common to all patients and scan types, such as the need to lie still for good pictures. To showcase variability in scans and experiences, three different scenarios for different characters were centered around the fundamental learning goals. The physical design of the Kitten Scanner was developed to be an intermediate between MRI and CT, such that it can be perceived as either a CT scanner or an MRI scanner.

Whereas the Scan Buddy app by its nature provided the ideal platform for gamification, we successfully added important elements to the Kitten Scanner as well. Given the limitations in time and context of use of the Kitten Scanner, we convincingly implemented gamification motivations such a social relatedness, empowerment, accomplishment and modeling behavior, ensuring a great stand-alone experience as well as a solid extended experience within the Pediatric Coaching suite of solutions.

The Kitten Scanner will provide a good basis for a pediatric patient to recognize and understand what to expect and do while having the scan, although additional effectiveness research is needed to corroborate this. The Kitten Scanner can enable and optimize preparation right before the scan by various health care professionals, besides the trained child life specialist. We expect children to be more knowledgeable, calmer, experience less fear and stress, and be more cooperative after interacting with the Kitten Scanner.

REFERENCES

1. S. A. Vanderby, P. S. Babyn, M. W. Carter, S. M. Jewell, and P. D. McKeever, “Effect of Anesthesia and Sedation on Pediatric MR Imaging Patient Flow,” *Radiology*, vol. 256, no. 1, pp. 229–237, Jul. 2010.
2. B. Walker, H. M. Conklin, D. L. Anghelescu, L. P. Hall, E. E. Reddick, R. Ogg, and L. M. Jacola, “Parent perspectives and preferences for strategies regarding nonsedated MRI scans in a pediatric oncology population,” *Supportive Care Cancer*, vol. 26, no. 6, 2018, pp. 1815–1824.
3. M. Artunduaga, C. A. Liu, C. E. Morin, S. D. Serai, U. Udayasankar, M. C. Greer, and M. S. Gee, “Safety challenges related to the use of sedation and general anesthesia in pediatric patients undergoing magnetic resonance imaging examinations,” *Pediatric Radiology*, vol. 51, no. 5, pp. 724–735, Apr. 2021.
4. C. Ing, D. O. Warner, L. S. Sun, R. P. Flick, A. J. Davidson, L. Vutskits, M. E. McCann, J. O'Leary, D. C. Bellinger, V. Rauh, B. A. Orser, S. Suresh, and D. B. Andropoulos, “Anesthesia and Developing Brains: Unanswered Questions and Proposed Paths Forward,” *Anesthesiology*, vol. 136, no. 3, pp. 500–512, Jan. 2022.
5. N. Useinovic and V. Jevtovic-Todorovic, “Controversies in Anesthesia-Induced Developmental Neurotoxicity,” *Best Practice & Research Clinical Anaesthesiology*, Mar. 2023
6. S. Liszio, L. Graf, O. Basu, and M. Masuch, “Pengunaut trainer,” *Proceedings of the Interaction Design and Children Conference*, Jun. 2020, doi: https://doi.org/10.1145/3392063.3394432.
7. P. Saini, C. Koehn, A. Heuvelink, O. Tasar, E. v. Vorstenbosch-Lynn, S. Nauts, and A. T. Trout, “Scan Buddy: A Gamified App to Prepare Children for an MRI Scan,” *Human-Computer Interaction. Theoretical Approaches and Design Methods*, pp. 594–612, 2022.
8. J. Ashmore *et al.*, “A Free Virtual Reality Experience to Prepare Pediatric Patients for Magnetic Resonance Imaging: Cross-Sectional Questionnaire Study,” *JMIR Pediatrics and Parenting*, vol. 2, no. 1, p. e11684, Apr. 2019, doi: https://doi.org/10.2196/11684.
9. J. Jacob, C. Stunden, Dhayanand Deenadayalan, and L. Thomas, “Economic Evaluation Comparing Virtual Reality with Child Life Programming for Non-sedated Pediatric Medical Imaging: A Cost-Consequence Analysis,” vol. 7, no. 3, pp. 417–429, Apr. 2023, doi: https://doi.org/10.1007/s41669-023-00409-y.
10. C. Stunden, K. Stratton, S. Zakani, and J. Jacob, “Comparing a Virtual Reality–Based Simulation App (VR-MRI) With a Standard Preparatory Manual and Child Life Program for Improving Success and Reducing Anxiety During Pediatric Medical Imaging: Randomized Clinical Trial,” *Journal of Medical Internet Research*, vol. 23, no. 9, p. e22942, Sep. 2021, doi: https://doi.org/10.2196/22942.
11. H. L. McGlashan, R. A. Dineen, S. Szeszak, W. P. Whitehouse, G. Chow, A. Love, G. Langmack, and H. Wharrad, “Evaluation of an internet-based animated preparatory video for children undergoing non-sedated MRI,” *The British Journal of Radiology*, p. 20170719, May 2018, doi: https://doi.org/10.1259/bjr.20170719.
12. S. S. Olloni, N. Viladsen, B. Mussmann, “Pediatric MRI Without Anesthesia: The Effect of Application-Supported Communication to Prepare the Child,” *Journal of* Radiology Nursing, vol. 40, no. 1, pp. 56–60, Mar. 2021, doi: https://doi.org/10.1016/j.jradnu.2020.09.002.
13. D. Hogan, T. DiMartino, J. Liu, K. A. Mastro, E. Larson, and E. Carter, “Video-based Education to Reduce Distress and Improve Understanding among Pediatric MRI Patients: A Randomized Controlled Study,” *Journal of Pediatric Nursing*, vol. 41, pp. 48–53, Jul. 2018, doi: https://doi.org/10.1016/j.pedn.2018.01.005.
14. H. S. Xu, R. M. Cavaliere, and R. J. Min, “Transforming the Imaging Experience While Decreasing Sedation Rates,” *Journal of the American College of Radiology*, Sep. 2019, doi: https://doi.org/10.1016/j.jacr.2019.08.005.
15. M. Perez, C. Cuscaden, J. F. Somers, N. Simms, S. Shaheed, L. A. Kehoe, S. A. Holowka, A. A. Aziza, M. M. Shroff, and M. C. Greer, “Easing anxiety in preparation for pediatric magnetic resonance imaging: a pilot study using animal-assisted therapy,” *Pediatric Radiology*, vol. 49, no. 8, pp. 1000–1009, Apr. 2019, doi: https://doi.org/10.1007/s00247-019-04407-3.
16. S. Szeszak, R. Man, A. Love, G. Langmack, H. Wharrad, and R. A. Dineen, “Animated educational video to prepare children for MRI without sedation: evaluation of the appeal and value,” *Pediatric Radiology*, vol. 46, no. 12, pp. 1744–1750, Aug. 2016, doi: https://doi.org/10.1007/s00247-016-3661-4.
17. B. Bharti, P. Malhi, and N. Khandelwal, “MRI Customized Play Therapy in Children Reduces the Need for Sedation - A Randomized Controlled Trial,” *The Indian Journal of Pediatrics*, vol. 83, no. 3, pp. 209–213, Oct. 2015, doi: https://doi.org/10.1007/s12098-015-1917-x.

18. S. Kekäläinen, M. Virtanen, K. Paalimäki-Paakki, A. Oikarinen, P. Kaakinen, and M. Kääriäinen, “Effectiveness of Digital Counseling Before Pediatric Diagnostic Imaging,” *Radiologic Technology*, vol. 94, no. 3, pp. 180–196, Jan. 2023.
19. S. Janos, G. R. Schooler, J. S. Ngo, and J. T. Davis, “Free-breathing unsedated MRI in children: Justification and techniques,” *Journal of Magnetic Resonance Imaging*, Jan. 2019.
20. S. G. Harrington, C. Jaimes, K. M. Weagle, M.-L. C. Greer, and M. S. Gee, “Strategies to perform magnetic resonance imaging in infants and young children without sedation,” *Pediatric Radiology*, Apr. 2021.
21. S. B. Runge, N. L. Christensen, K. Jensen, and I. E. Jensen, “Children centered care: Minimizing the need for anesthesia with a multi-faceted concept for MRI in children aged 4–6,” *European Journal of Radiology*, vol. 107, pp. 183–187, Oct. 2018.
22. J. V. Chen, M. A. Zapala, A. Zhou, N. Vu, L. Meyer, M. D. Smith, C. Kelleher, O. A. Glenn, J. Courtier, and Y. Li, “Factors and Labor Cost Savings Associated with Successful Pediatric Imaging without Anesthesia: a Single-Institution Study,” *Academic Radiology*, Jan. 2023.
23. Suzuki, R. Yamaguchi, L. Kim, T. Kawahara, and A. Ishii-Takahashi, “Effectiveness of mock scanners and preparation programs for successful magnetic resonance imaging: a systematic review and meta-analysis,” Pediatric Radiology, Jun. 2022, doi: https://doi.org/10.1007/s00247-022-05394-8.
24. E. Cavarocchi, I. Pieroni, A. Serio, L. Velluto, B. Guarnieri, and S. Sorbi, “Kitten Scanner reduces the use of sedation in pediatric MRI,” *Journal of Child Health Care*, vol. 23, no. 2, pp. 256–265, Jul. 2018.
25. N. Barnea-Goraly, S. A. Weinzimer, K. J. Ruedy, N. Mauras, R. W. Beck, M. J. Marzelli, P. K. Mazaika, T. Aye, N. H. White, E. Tsalikian, L. Fox, C. Kollman, P. Cheng, A. L. Reiss, and & Diabetes Research in Children Network (DirecNet), “High success rates of sedation-free brain MRI scanning in young children using simple subject preparation protocols with and without a commercial mock scanner–the Diabetes Research in Children Network (DirecNet) experience,” *Pediatric Radiology*, vol. 44, no. 2, pp. 181–186, Oct. 2013.
26. S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth, “Active learning increases student performance in science, engineering, and mathematics,” *Proceedings of the National Academy of Sciences*, vol. 111, no. 23, pp. 8410–8415, May 2014.
27. A. M. Glenberg, “Embodiment as a unifying perspective for psychology,” *Wiley Interdisciplinary Reviews: Cognitive Science*, vol. 1, no. 4, pp. 586–596, Apr. 2010.
28. M. Macedonia, “Embodied Learning: Why at School the Mind Needs the Body,” *Frontiers in Psychology*, vol. 10, Oct. 2019.
29. W. Zhang, Z. Chen, and R. Zhao, “A Review of Embodied Learning Research and its Implications for Information Teaching Practice,” *IEEE Xplore*, Jun. 01, 2021.
30. L. W. Barsalou, “Grounded Cognition,” *Annual Review of Psychology*, vol. 59, no. 1, pp. 617–645, Jan. 2008.
31. D. Geary, “An Evolutionarily Informed Education Science,” *Educational Psychologist*, vol. 43, no. 4, pp. 179–195, Oct. 2008.
32. F. Paas and J. Sweller, “An Evolutionary Upgrade of Cognitive Load Theory: Using the Human Motor System and Collaboration to Support the Learning of Complex Cognitive Tasks,” *Educational Psychology Review*, vol. 24, no. 1, pp. 27–45, Sep. 2011.
33. M. Li, B. Rudd, T. C. Lim, and J.-H. Lee, “In situ active control of noise in a 4 T MRI scanner,” *Journal of Magnetic Resonance Imaging, vol. 34, no. 3, pp. 662–669, Jul. 2011, doi: https://doi.org/10.1002/jmri.22694.*
34. N. Sharifzadeh, H. Kharrazi, E. Nazari, H. Tabesh, M. Edalati Khodabandeh, S. Heidari, and M. Tara, “Health Education Serious Games Targeting Health Care Providers, Patients, and Public Health Users: Scoping Review,” *JMIR Serious Games,* vol. 8, no. 1, p. e13459, Mar. 2020, doi: https://doi.org/10.2196/13459.