Guiding children during their MRI exam: the design and usability study of an in-bore experience

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Abstract

Background: For pediatric patients, undergoing an MRI exam can be a stressful experience. To support children to undergo their exam awake, we recently developed solutions to prepare children for their MRI, at home with an app, and in the waiting room with an educational mock scanner. Although preparation is an effective means to be able to scan young children awake, it is also important to guide them during the exam in a way that they understand and like.

Objective: To create a patient guidance solution during the MRI exam, tailored to the needs of young children. By using elements (characters, visuals, voice, and language use) that were designed for our solutions to prepare children before their MRI exam, we aim to deliver a familiar experience to pediatric patients. To evaluate whether children like and understand the developed ‘pediatric In-bore experience’ solution consisting of pediatric themes, pediatric AutoVoice, and pediatric In-bore Connect featuring three guidance overlays (breath-hold guidance; exam progress bar, animated Ollie), we conducted a usability study.

Methods: Ten children (aged 5 to 10) participated in a mock MRI exam that included pediatric In-bore experience. Task compliance (ability to lie still and hold one’s breath) was observed, and in a guided interview the experience and understanding of the different elements of pediatric In-bore experience were evaluated.

Results: Overall, participants were positive about pediatric In-bore experience. Ollie and the pediatric theme were liked. Pediatric AutoVoice, and the guidance overlays were generally liked and understood, but we learned that the auditory guidance during the breath-hold scan was difficult to interpret. All but one participant were able to complete the tasks successfully.

Conclusions: Pediatric In-bore experience is a promising approach to engage and guide young children during MRI exams. With it we have completed the Pediatric Coaching solution, a holistic solution covering the full patient journey for a child requiring an MRI. As a next step the impact of the complete Pediatric Coaching solution on patient experience and the clinical workflow could be investigated.

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Keywords: MRI; pediatrics; patient guidance; patient experience; radiology; end-to-end solution

Introduction

Background

Using Magnetic Resonance Imaging (MRI), physicians can diagnose a host of different pediatric conditions without exposing children to harmful ionizing radiation. Every year, millions of children get an MRI exam. To be able to have a successful exam, children need to enter a room with a large machine, lie down on a table that slides into this machine, and keep very still for up to an hour. For some exams, children need to hold their breath during various scans to enable physicians to create sharp images of the child's heart or abdomen. During the exam, the MRI scanner makes very loud noises. Children report that this noise and boredom are the most stressful factors of having an MRI [1].

Given these challenges, young children are often scanned using general anesthesia or sedation, which enables high quality scans along with a smooth and predictable workflow. Unfortunately, using anesthesia or sedation is costly, and waiting lists are typically longer for exams with

anesthesia/sedation than for awake exams [2]. More importantly, there are concerns about the potential effect of repeated anesthesia exposure on children's neurodevelopment (for an overview, see [3-5]). For these reasons, an increasing number of hospitals are trying to scan children awake.

Existing solutions

There are many initiatives to support hospitals that aim to scan children awake (see [6] for a review). Some initiatives focus on preparing children at home, for example using a gamified app or Virtual Reality (e.g., [7-13]). Other initiatives focus on preparing children in the hospital, for example using face-to-face training programs with child life specialists [14,15], or educational (mock) scanners (e.g., [16], for a review see [17]). During the MRI exam, children can sometimes watch a movie in the bore of the MRI scanner (e.g., using movie goggles or a screen), play an interactive game [18,19], or enjoy a child-friendly imaging room (for a review of different approaches, see [20]).

Next to initiatives that focus on one specific touchpoint in a child's diagnostic pathway (such as interventions at home *or* in the hospital *or* in the MRI room), there are multi-faceted concepts that cover the entire pathway from home to exam. An example of such a holistic approach is Children Centered Care [21], which prepares children at home (with an app), in the hospital (using an educational scanner), and supports them during their MRI exam with a child-friendly imaging room. The Pingunauten program [7,8,18] prepares children at home, but also provides an in-bore game featuring the same child-friendly characters and theme (pinguins in space) as the Pingunauten-app.

Consistently using certain design elements (e.g., characters, visuals, voices, and terminology) throughout multiple touchpoints in the care pathway can provide children with a sense of familiarity. Providing such a sense of familiarity in an otherwise unfamiliar, stressful medical setting can give children and their parents a sense of comfort, continuity, and safety [22]. Using recognizable elements like characters can also provide staff with a starting point for conversation, helping them build rapport with the child.

In the current paper, we describe the design and usability study of pediatric In-bore experience, which is part of a holistic solution to prepare children for their exam and guide them throughout: the Pediatric Coaching solution (see Figure 1). The Pediatric Coaching solution started with the creation of a gamified mobile app to prepare children at home (Scan Buddy; [23]), followed by a redesign of an educational scanner for the waiting room (the Kitten Scanner; [24]). This Kitten Scanner was designed to feature the same design elements, voice, and terminology as Scan Buddy. In the next section of this paper, we elaborate on the design of pediatric In-bore experience to complement Scan Buddy and the Kitten Scanner. All elements feature a child-friendly elephant that is well-liked by children: Ollie the Elephant [25].

Figure 1. The complete Pediatric Coaching solution consists of the Scan Buddy app (left), enabling preparation at home days prior to the exam; the Kitten Scanner (middle), enabling preparation on-site moments before the exam; and Pediatric in-bore experience (right), providing guidance during the exam reusing familiar elements from the preparation.

In-bore experience

Pediatric In-bore experience is a child-friendly adaptation of an existing In-bore experience solution that engages and guides patients during their exam. In-bore experience is enabled by the following (see Figure 2):

a) A wall projection that patients can see when they enter the MRI room;
b) A screen that patients can see when they are in the bore of the MRI scanner;
c) Dynamic colored lighting that matches the colors of the visual content displayed on the wall projection and in-bore screen.

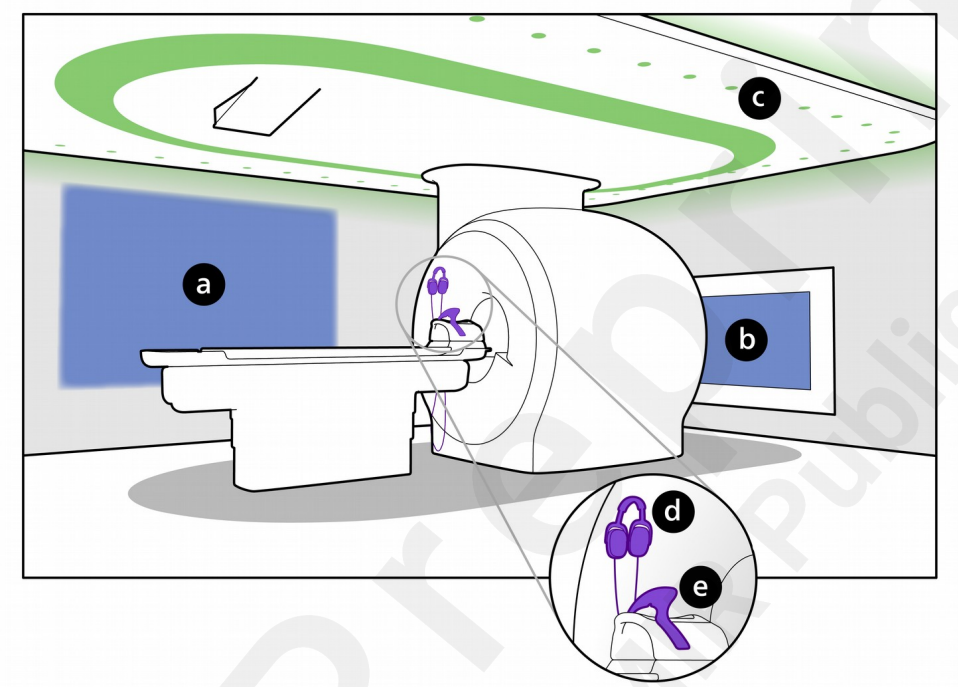


Figure 2. The elements enabling in-bore experience are a) Wall projection; b) In-bore screen; c) Dynamic lighting; d) Headphones; e) Mirror.

During the MRI exam, patients can look outside the bore using a mirror (Figure 2e). In this mirror, they can see a screen (located outside the bore) showing audiovisual content, such as a movie. Patients wear headphones (Figure 2d) to hear the music or audio accompanying the content displayed on the screen. They can also use these headphones to communicate with staff, and to hear automated voice messages. These automated messages (“AutoVoice”) instruct patients about when to hold still because the table moves, and how to breathe during a breath-hold scan. They also inform patients about the duration of the upcoming scan (e.g., “The next scan will last for three minutes”).

Taken together, these elements aim to guide and support patients when they enter the MRI room, and while they are in the scanner. Supporting patients in the MRI room is important, as patients’ physiological anxiety levels are relatively high at the beginning of an MRI exam, with a peak when patients enter the bore [26]. Providing patients with information during the examination (e.g., to inform them about how long the exam lasts), is associated with lower cortisol levels (an important indicator of physiological stress; [27]).

Design of pediatric In-bore experience

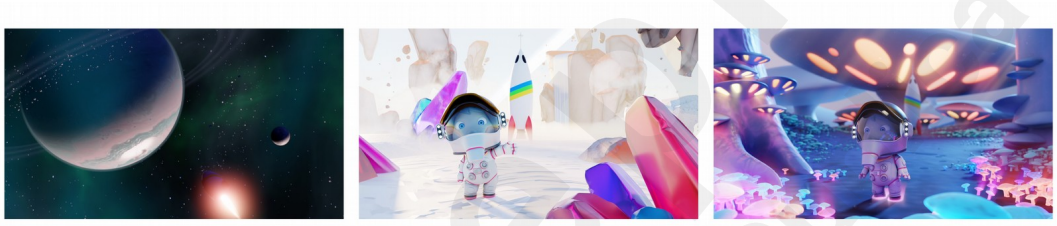
Solution elements

Pediatric In-bore experience consists of three distinct elements: pediatric audiovisual themes, pediatric AutoVoice and pediatric In-bore Connect. In this section, we describe the design rationale for each of these elements and how they differ from the existing In-bore experience that was developed for adults.

Themes

Themes consist of a videoclip with sounds and music for the wall projection and in-bore screen, and associated lighting patterns for the dynamic lightning (see Figure 2). There are themes for adults as well as children, and patients can choose which theme(s) they want to watch.

To complement the Pediatric Coaching solution, new videos were created featuring three characters: Ollie the Elephant, Chris the Crocodile, and Doris the Chicken. Children have been familiarized with these characters with the Kitten Scanner and (for Ollie) with the Scan Buddy app. Each character has his or her own story (see Figure 3). The goal of themes is to engage children and prevent boredom and as such support them with lying still.



In the Ollie theme, Ollie flies in her rocket through space and visits different magical planets.

In the Chris theme, Chris travels by van between different sports activities.

In the Doris theme, Doris walks down the street looking at shop windows. Upon seeing different objects, she magically transforms and uses them like a pro.

Figure 3. Screenshots of the three pediatric themes created with the characters of the Pediatric Coaching solution: Ollie the elephant (top); Chris the crocodile (middle); and Doris the chicken (bottom).

The themes were designed with a storyline (e.g., “Ollie’s space journey”) that consists of several substories (e.g., “Ollie visits an underwater planet”, “Ollie visits a mushroom-planet”, etc.) separated by a repetitive scene (e.g., “Ollie in her rocket”). This set-up was chosen because the length of an MRI exam can differ considerably; the modular set-up ensures that children do not miss an exciting

part of a story, because the exam finished midway.

Given that, in some cases, even minor motion during an MRI scan can negatively affect image quality [28], themes were designed with one central focus. This means that action (e.g., movement of characters) took place in the middle of the screen, and not at the edges (or periphery), to limit eye and head movement while watching the video.

AutoVoice

Pediatric AutoVoice is a version of AutoVoice redesigned to provide a consistent experience throughout the Pediatric Coaching solution. The existing "adult" AutoVoice was transformed into a pediatric version tailored to the needs of young children by making several changes elaborated on below.

Voice

For all 15 languages in which pediatric AutoVoice was created, we worked with the same voice actors as in the Scan Buddy app and Kitten Scanner. This was done to ensure that children hear the same voice at home, in the hospital, and in the MRI scanner. While adult AutoVoice has a practical, professional tone-of-voice, pediatric AutoVoice has an encouraging, lively tone-of-voice, using more inflection.

Language use/terminology

The language used in pediatric AutoVoice was tailored to young children by:

- Using informal language for those languages that have a distinction between formal and informal language (e.g., Sie/Du in German; jij/u in Dutch).
- Using the terminology used throughout the Pediatric Coaching solution, which is a child-friendly version of the terminology used for adults. For example, where adult AutoVoice uses terminology such as 'table' and 'scan', pediatric AutoVoice uses terminology such as 'bed' and 'picture'.
- Uses generic time indicators to indicate the duration of the next scan. For example, where adult AutoVoice says "the next scan will last for half a minute", pediatric AutoVoice says "The next picture will be really quick".

Timing

Providing automated breathing instructions is an important feature of adult AutoVoice. During a so called breath-hold scan, the patient is instructed to "Breathe in… breathe out… and hold your breath", after which the scanner starts acquiring data. When acquisition is finalized, the patient is told "You may breathe again".

On average, children have higher breathing rates than adults [29]; as such, the AutoVoice timing was adjusted to better match children's natural breathing pattern. In adult AutoVoice, on average, patients are instructed to breathe in and breathe out in approximately 2.5 seconds each (the exact length can differ across languages). This resembles a breathing frequency of 12 breaths per minute, which is at the low end of the natural breathing range spectrum for adults at rest.

For pediatric AutoVoice, we ensured that instructions had the same timing for all languages and shortened them to accommodate children's natural breathing rate. In particular, the "Breathe in…" and "breathe out…" instructions were timed 2 seconds apart, in accordance with a breathing frequency of 15 breaths per minute. With these instructions, we enable children to deeply breathe in a rhythm that matches their age, as 15 BPM is at the low end of the natural breathing range spectrum

for young children at rest [29].

In-bore Connect

In-bore Connect enables real-time visual patient guidance through a link with the MRI scanner. From the information received in real-time from the scanner about breath-hold scans and scan progress, overlays are constructed that are superimposed on the content displayed at the screen.

Breath-hold guidance (visual)

When a breath-hold scan is coming up, AutoVoice informs the patient that the next scan is a breath-hold scan. To capture the patient's attention, the content is dimmed, the progress bar hidden, and a 'breathe' icon is displayed in the center of the screen. The moment the patient is instructed to hold their breathing, the icon changes and the circle that surrounds it is progressively filled to indicate the remaining time (Figure 4).

Figure 4. Visual breath-hold guidance by alternately displaying a breathing icon (top) and a breath-hold icon + animated progress circle (bottom).

For pediatric In-bore Connect, the visuals of the breath-hold guidance were redesigned to have a more familiar and playful component. Upon announcing the breath-hold scan, the pediatric 'breathe' icon is accompanied by Ollie, who encouragingly points to it to support the child to pay attention to

what is coming next. The moment the child is instructed to hold their breath, the icon changes and the circle is animated to indicate the remaining time. Upon completing the breath-hold, the icon changes back to the ‘breathe’ icon and stars appear as a small reward for completing the breath-hold (see Figure 5).

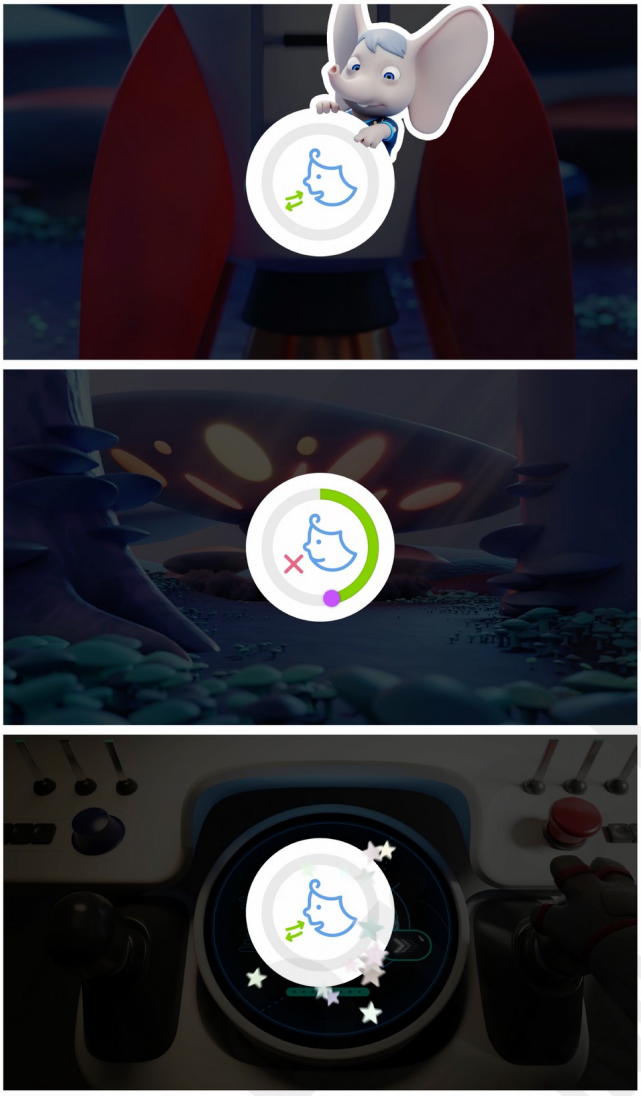


Figure 5. Stills of the breath-hold visual guidance: breath-hold scan announcement displaying the ‘breathe’ icon and Ollie (top); breath-hold progress displaying the ‘hold your breath’ icon and the progress (middle); and breath-hold completed displaying the ‘breathe’ icon and celebrative stars (bottom).

Progress bar

During the MRI exam, In-bore Connect enables the overlay of a progress bar at the bottom of the screen on top of the content shown. The progress bar indicates the total number of scans, their length, and the examination progress (Figure 6).

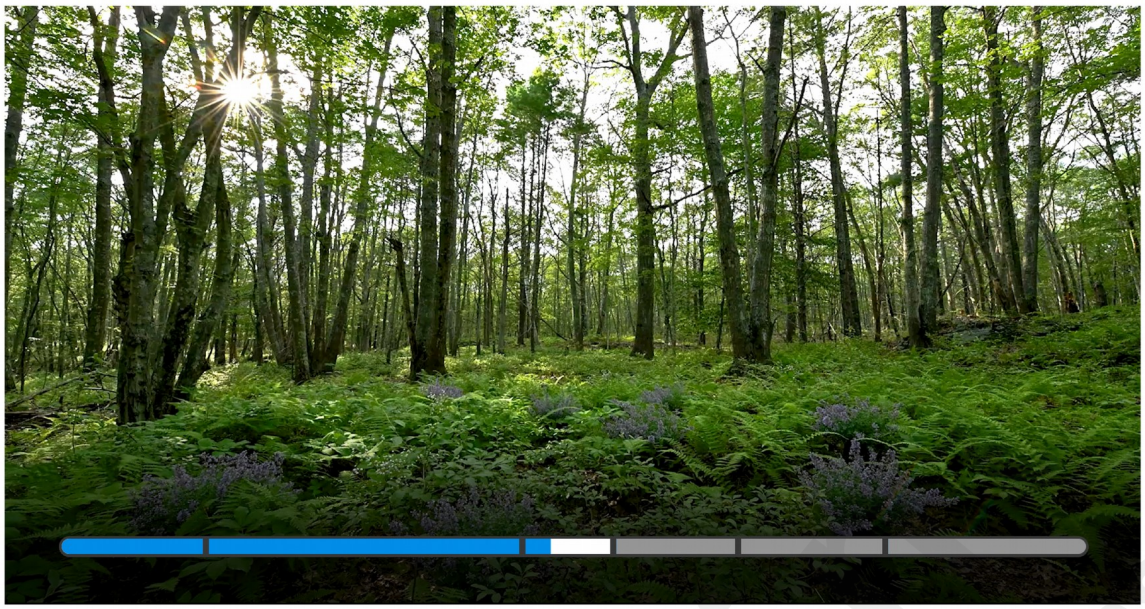


Figure 6. Example progress bar that shows the following: the first two scans have been completed, the third scan is ongoing, and three scans are remaining.

For pediatric In-bore experience, the progress bar was redesigned in such a way that it appeals to children and has the same familiar look and feel as the progress bar introduced in the Scan Buddy app and the Kitten Scanner (Figure 7).

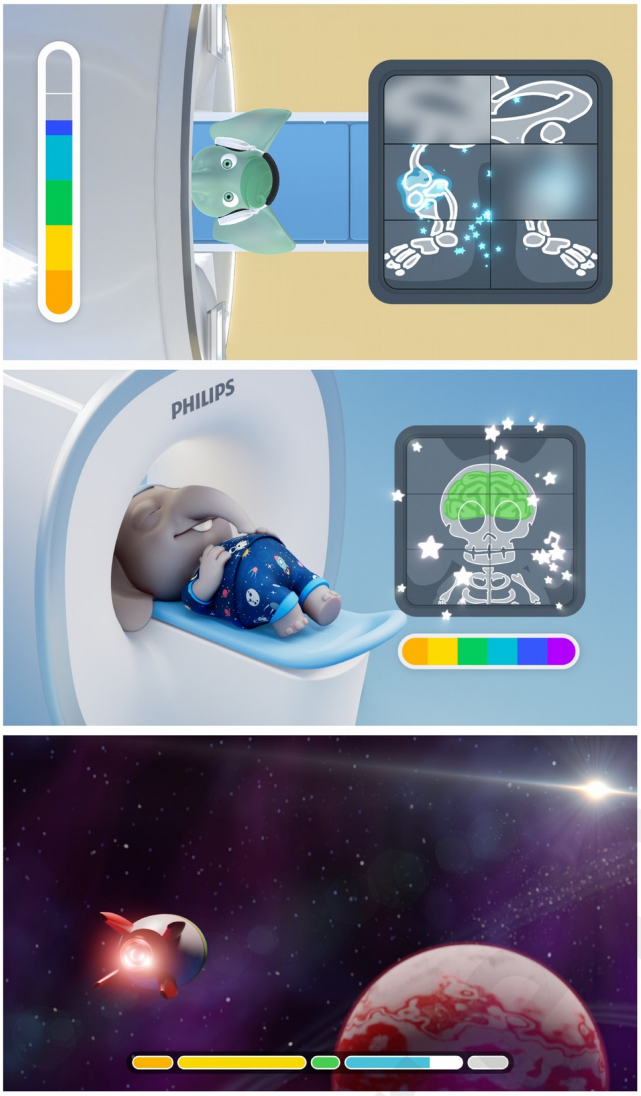


Figure 7. Examples of the color-full progress bar in the Scan Buddy app (top); the Kitten Scanner (middle); and pediatric In-bore experience (bottom).

Animated Ollie

Next to redesigning the breath-hold guidance and progress bar overlays, Pediatric In-bore Connect introduces an animated Ollie as third type of overlay. This animated Ollie is visible at the start and the end of the exam and displays various gestures like waving to the patient (see Figure 8).

Figure 8. At the start (top) and end (bottom) of the MRI examination Ollie the elephant actively welcomes and says goodbye to the child.

The goal of showing Ollie at the start of the exam is to actively engage and distract young children when they lie down on the table and the table slides into the MRI scanner, as this is a moment of high anxiety for patients [26]. As soon as the first scan starts, Ollie disappears and the progress bar starts filling, informing the child about the progress of the examination. When all the scans are finished and the progress bar has completely filled, Ollie pops up again. In this way, Ollie creates a small celebratory moment when the exam has been completed. She also bridges the time between finishing the last scan, and the operator coming into the room and moving the child out of the scanner.

Pediatric In-bore experience usability study

Methods

Study setup

To investigate whether children would like and understand pediatric In-bore experience, we conducted a usability study. Healthy participants (N = 10) aged 5 to 10 were invited for a short mock

MRI exam, during which they were exposed to all the different elements of pediatric In-bore experience: a pediatric theme, pediatric AutoVoice (in their native language) and the three overlays of pediatric In-bore Connect.

The mock exam was conducted in a usability lab featuring a mock scanner that looks exactly like a functional MRI scanner (see Figure 9). To simulate the full pediatric In-bore experience during a real MRI exam, all the visuals (theme as well as overlays) and sounds (MRI scanner sounds as well as AutoVoice and theme sounds) were prerecorded and assembled into one video displayed on a screen behind the bore, which children could see and hear using an MRI mirror and headphones.

Figure 9. The usability lab where the study was conducted.

Each study session was facilitated by a researcher (who led the study) and one or two observers who logged participants' responses. Sessions were recorded to help observers code participants' behavior inside the bore.

The study lasted a maximum of 1 hour per participant.

Recruitment

Participants were recruited by an external agency. Parents were paid a small fee to cover any expenses, while the children received a small gift package related to the Pediatric Coaching solution (small elephant snuggle, stickers, magnets and coloring book).

Outcomes

The main goal of the study was to investigate to what extent pediatric In-bore experience was understood, liked, and considered helpful for undergoing an MRI exam. As a secondary outcome, we

gauged the ability of the child to lie still during the exam and to follow the breath-hold instructions.

Study procedure and materials

Study sessions all started with a general introduction of what an MRI machine is and what it is used for, followed by an explanation of the study procedure. After that the Informed Consent was signed by the parent(s) and a walk-through of child assent was done.

The main part of the study consisted of the mock exam of approximately 10 minutes. First, the child was equipped with a small camera on their head to enable the observers to inspect the behavior of the child when lying in the MRI scanner. Next, they were asked to climb onto the MRI bed. They were asked to lie as still as they could, like children undergoing a real MRI, and to watch the video and follow any instructions that were provided in the video. Then, they were donned with headphones so they could hear the audio embedded in the study video. The mirror was positioned, after which the bed was moved into the bore. While lying in the bore the child watched the study video mimicking an MRI exam containing 5 MRI scans including 1 breath-hold scan.

Throughout the study video the Ollie theme was playing full screen, accompanied by the progress bar displaying the exam progress (see bottom Figure 7). Pediatric AutoVoice announced the duration for each of the non-breath hold scans and provided instructions throughout the breath-hold scan. The middle scan was the breath-hold scan containing 4 breath-holds, during which the breath-hold guidance was shown. During breath-hold guidance the theme was dimmed and the progress bar invisible (see Figure 5). At the start and the end of the study video Animated Ollie was shown (see Figure 8).

The last part of the study was a guided interview to learn about the child's experience during the mock exam and their opinion about the various elements of pediatric In-bore experience. This part was approximately 35 minutes. To facilitate a smooth interview, screenshots of the study video were used to jog participants' memory, and printed probes - line drawings of children with various emotions - were used to encourage talking and expression of feelings (see Figure 10).

Figure 10. Impression of the material used during the interview.

Measures

To estimate how well the child executed the various parts of the mock exam (‘Tasks’), children’s behavior was observed both directly as well as during data analysis (using the video recording made inside the bore). For each task (see Table 1), the extent to which the child was able to perform it was noted (unsuccessful, successful with minor issues, or successful).

Table 1. The tasks embedded in the mock exam in chronological order and the intended behavior of the child for each of them.

Tasks	Intended behavior
Lying down, going into the bore, and viewing animated Ollie	Going in without issues; watching the animation without movement
Lying still during the first two scans	Lying still without movement
Executing the breath-holds during the middle, breath-hold scan	Correctly executing the four breath-holds (holding their breath in exhale)
Lying still during the last two scans	Lying still without movement
Viewing animated Ollie	*NA – positive sentiment*

The guided interview after the mock exam contained open questions and questions the child could answer by pointing to a position on a printed slider showing three emoticons (visible in the middle of Figure 10). For data analysis the sentiment of the answers to the open questions were interpreted on a 3-point scale (e.g., negative, neutral, positive), while the slider position was interpreted as a 5-point scale (see Table 2 for a full list of the measures).

Table 2. List of outcomes for the various elements of pediatric In-bore experience.

	Outcomes
Complete pediatric In-bore experience	
	Overall exam experience
	Understanding when to lie still
	Ease of lying still
	Pediatric In-bore experience considered helpful
	Knowing what to do
Ollie theme	
	Likability of Ollie the Elephant
	Likability of the Ollie Theme
Pediatric AutoVoice	
	Likability of the voice
	Understanding of scan (duration) information
	Understanding of verbal breath-hold guidance
	Perceived ability to follow breath-hold guidance
Breath-hold guidance (visuals)	
	Understanding of visual breath-hold guidance
	(*copy*) Perceived ability to follow breath-hold guidance
Progress bar	
	Understanding the progress bar
	Knowing when the first scan started
	Knowing when the last scan ended
Animated Ollie	
	(*copy*) Likability of Ollie the Elephant
	Understanding the intent of animated Ollie at the start
	Understanding the intent of animated Ollie at the end

Results

Participants

Ten healthy children (4 male, 6 female) in the ages 5-10 with M=7,6 participated. One child (5-year-old girl) was unable to perform the tasks of going into the scanner and lying still long enough to experience the full mock exam, and thus we exclude her data from the results discussed below.

Task success

All 9 participants were able to perform the 5 tasks successfully, or with minor issues. All the tasks were completed equally successfully, except the breath-holding during the breath-hold scan. Only 1 participant perfectly executed the 4 breath-holds while 8 of the 9 participants completed this task

with some issues. When enquiring how easy they found it to hold their breath, 2 indicated they found it a bit difficult, 3 said they found it pretty easy, and 4 found it very easy.

When explicitly asked if they knew when they had to lie still, 2 indicated that they really did not know, and the rest called a solid yes. Upon enquiring how easy they found it to lie still, 6 out of 9 indicated they found it very easy with the remaining 3 finding it pretty easy.

Overall experience

When discussing their general experience of undergoing the mock exam, no one was negative, 2 were neutral and 7 were positive. Upon enquiring whether they were helped by Ollie and the lady's voice while lying in the bore, 1 was neutral, 2 were slightly positive, while 6 participants gave a solid yes. When asked whether they knew what to do, 8 out of 9 participants said yes but 1 said no.

Likability of the Ollie character and theme

Out of 9 participants, 1 had neutral feelings about Ollie, 8 liked Ollie a lot, and no one had negative feelings. Results were the same for likability of the Ollie theme, with the same child having neutral feelings about the character and theme.

Pediatric AutoVoice

Seven participants indicated that they understood the content of AutoVoice well during the exam and these same 7 also liked the voice. Two were neutral about both the content and the voice. All 9 participants said they understood the breathing instructions that were given.

Breath-hold guidance (visual)

All 9 participants indicated that they understood the visual guidance during the breath-hold scan and found it easy to follow. However, the observers note that even though the participants reported that they were able to follow instructions, almost all of them did some breath-holds 'wrongly'. Instead of breathing out and then holding – as the AutoVoice said and visual guidance showed – many participants took a quick breath in before holding.

Progress bar

Eight out of 9 participants understood the progress bar and were able to explain it in their own words, e.g., "That was really nice. Because, when it was a short one, it has a short bar, and the long one that took a long time, there was a long one. And every time it made a different sound with the bar. […] It was really handy, because you sort of knew when you'd be done". Only 1 participant mentioned not seeing or noticing the progress bar. That same participant was also the 1 to indicate not to know when the last scan was finished, as well as one of the 2 that said to not have known when the first scan started.

Animated Ollie

The animated Ollie was not clearly identifiable or memorable for all participants in comparison to the Ollie shown in the theme. When asking the participants about Ollie and what they thought Ollie was doing, they often started to explain the theme's story line. By explicating that we were interested in what they thought the animated Ollie was doing, 7 of 9 indicated that Ollie was waving hi, or welcoming them at the start of the exam, and waving goodbye, or applauding them at the end, e.g., "He means like good job. I saw it because of the wink, because when you wink it often means you did a good job".

Discussion

Principal results

Overall, participants were positive about pediatric In-bore experience and indicated it helped them during the exam. (Animated) Ollie and the theme were liked, and pediatric AutoVoice and accompanying breath-hold guidance and progress bar overlays were generally liked and understood.

Also, undergoing the mock exam and doing the various tasks were manageable. Except for one participant, all were able to complete all tasks with only minor issues. In fact, some issues were so minor (moving/tapping their fingers during one of the 'lying still' tasks) that in a real exam they would not impact the diagnostic quality of the acquired images.

Although the experience of the mock exam was generally positive, the conversations revealed that it was an impressive experience, even with the scanner being in an office environment and the participants knowing that were not really being scanned. The fact that one of the youngest participants really struggled during the mock exam emphasizes the need to prepare children in a safe environment before their exam.

Breath-hold guidance

Of all the tasks, correct execution of the breath-holds was clearly the most difficult. Children self-reported it - as having understood and the ease of executing it - with less confidence than the other tasks. The AutoVoice said "Breathe in… breathe out and hold your breath" with the visual guidance enforcing that instruction. Objectively, we observed the children make solid attempts, only to go wrong at the most crucial moment: taking a breath, when they should have paused breathing after exhaling.

When discussing their performance, several children – including ones that paused their breathing at the correct moment – questioned the accuracy of the instructions. For example, one participant remarked "Hold your breath, I did not get that completely. Because it was breathe in, breathe out, and hold your breath, but how is that possible? Because your breath is already gone!". Since holding one's breath is familiar to children after inhaling (i.e., this is what many children learn during swimming lessons), the counter-intuitive instructions of holding after exhaling were difficult to accept and adhere to. Emotionally, the breath-hold scan was one of the most discussed and commented parts of the mock exam with some participants expressing feelings of pride of being able to hold their breath and others elaborating on similar breath-holding experiences, e.g., during swimming under water.

Only a small portion of pediatric exams are made of the upper body and therefore impacted by breathing motion. Because it is known that breath-hold scans are challenging for young children, commonly other scan types that compensate for breathing motion are used in clinical practice. In case a breath-hold scan is needed, our usability study indicates that an explanation of the expected behavior and practicing with the child to hold their breath after exhaling would be advisable. In the future we may extend our solutions to prepare children for their exam with a dedicated section on breath-hold scans.

Conclusions

Pediatric In-bore experience is a promising approach to engage and guide young children during MRI exams. Given the ongoing debate on the safety of repeated use of anesthesia and sedation in young children, it is crucial to find solutions to scan children

awake that are safe, effective, and child-friendly. The usability study demonstrates that the created pediatric In-bore experience, featuring child-friendly themes, automated voice instructions tailored to children, and three types of informative and engaging overlays, is well-liked and understood by children aged 5-10. Future research can expand this work by testing pediatric In-bore experience with a larger sample size, and in a clinical setting.

With pediatric In-bore experience we have completed a holistic solution covering the full patient journey, with preparation upfront at home and in the hospital, and guidance throughout the MRI examination. This Pediatric Coaching solution has the potential to improve the MRI experience for children, reduce the need for sedation and anesthesia, and ultimately improve overall patient outcomes. As a next step, the impact of the complete Pediatric Coaching solution on patient experience and the clinical workflow could be investigated.

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Conflicts of Interest

The authors are employees of Philips.

Abbreviations

MRI: Magnetic Resonance Imaging

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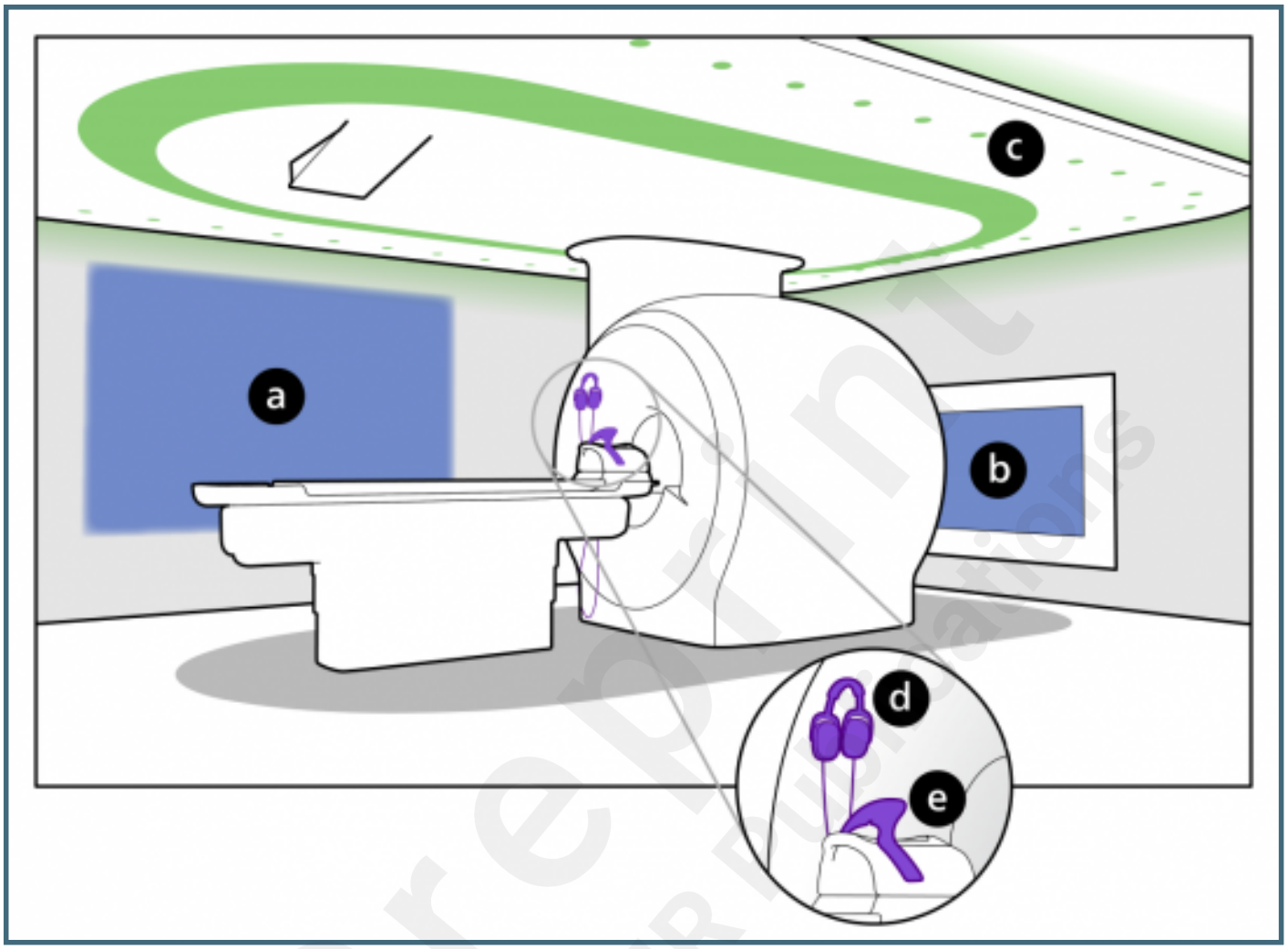
Supplementary Files

Figures

The complete Pediatric Coaching solution consists of the Scan Buddy app (left), enabling preparation at home days prior to the exam; the Kitten Scanner (middle), enabling preparation on-site moments before the exam; and Pediatric in-bore experience (right), providing guidance during the exam reusing familiar elements from the preparation.

The elements enabling in-bore experience are a) Wall projection; b) In-bore screen; c) Dynamic lighting; d) Headphones; e) Mirror.



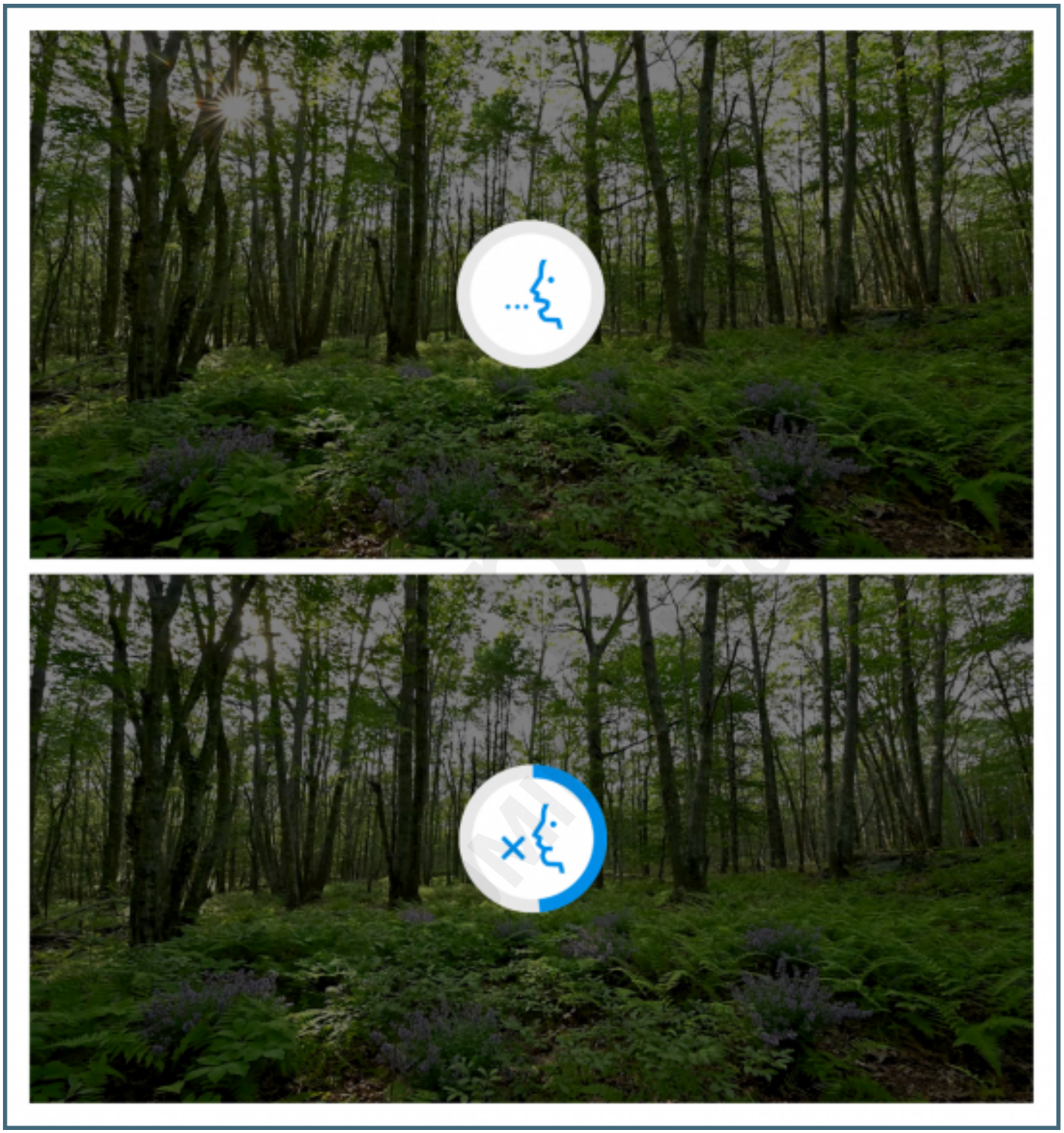
Screenshots of the three pediatric themes created with the characters of the Pediatric Coaching solution: Ollie the elephant (top); Chris the crocodile (middle); and Doris the chicken (bottom).

In the Ollie theme, Ollie flies in her rocket through space and visits different magical planets.

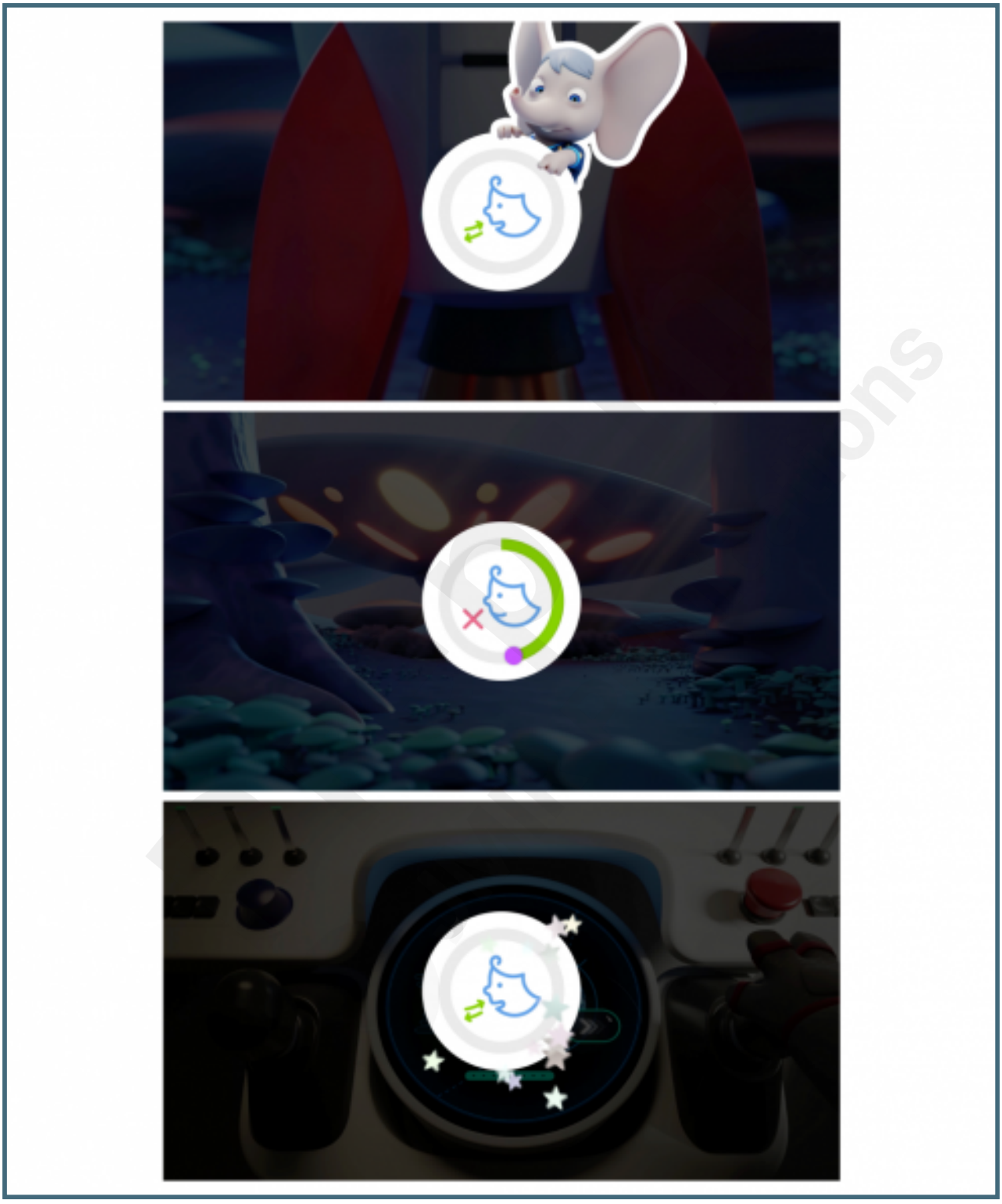
In the Chris theme, Chris travels by van between different sports activities.

In the Doris theme, Doris walks down the street looking at shop windows. Upon seeing different objects, she magically transforms and uses them like a pro.

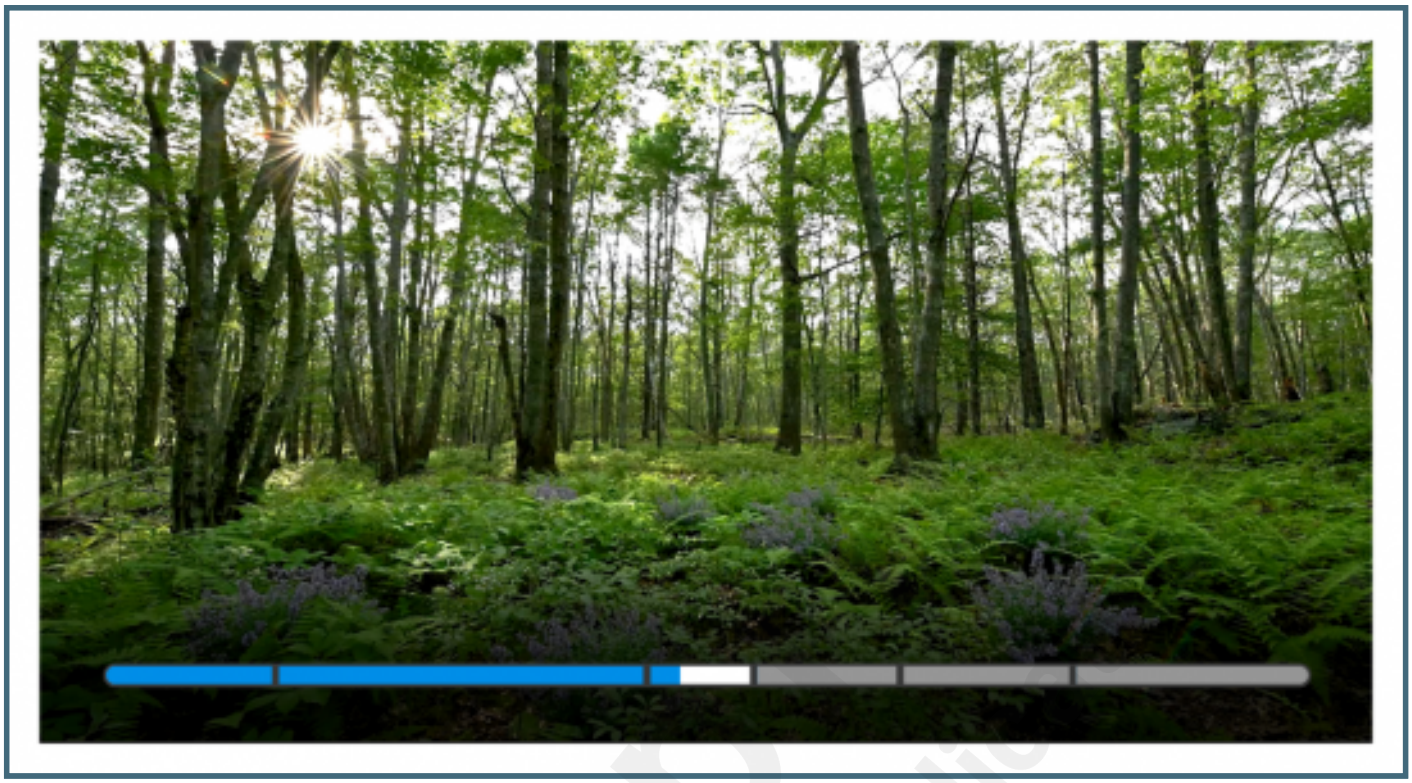
Visual breath-hold guidance by alternately displaying a breathing icon (top) and a breath-hold icon + animated progress circle (bottom).



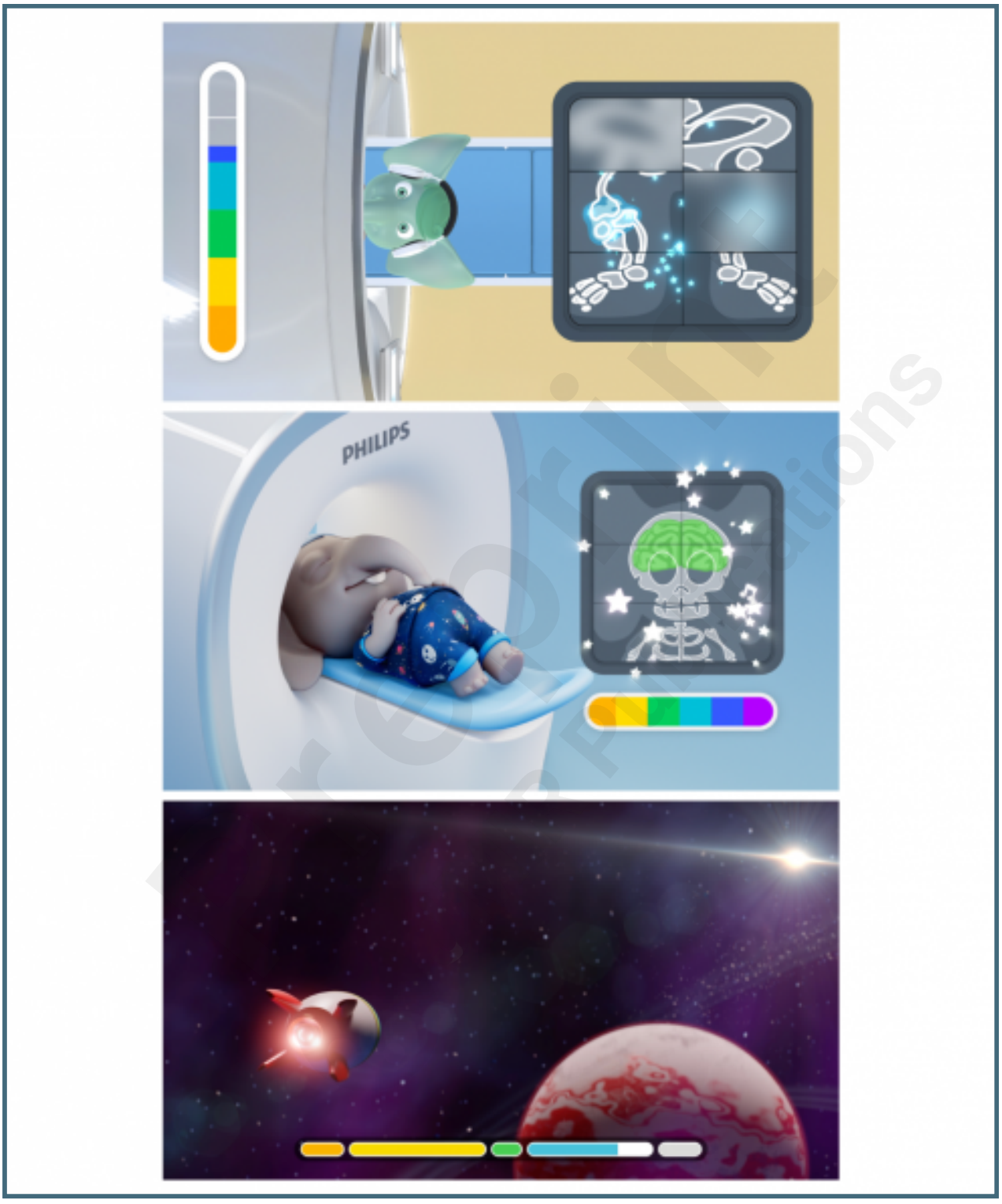
Stills of the breath-hold visual guidance: breath-hold scan announcement displaying the ‘breathe’ icon and Ollie (top); breath-hold progress displaying the ‘hold your breath’ icon and the progress (middle); and breath-hold completed displaying the ‘breathe’ icon and celebrative stars (bottom).



Example progress bar that shows the following: the first two scans have been completed, the third scan is ongoing, and three scans are remaining.



Examples of the color-full progress bar in the Scan Buddy app (top); the Kitten Scanner (middle); and pediatric In-bore experience (bottom).



At the start (top) and end (bottom) of the MRI examination Ollie the elephant actively welcomes and says goodbye to the child.

The usability lab where the study was conducted.

Impression of the material used during the interview.