Design Directions for Robot Characters in Pediatric Eye Exams

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***Abstract*— Eye imaging in children, especially high-resolution imaging like Optical Coherence Tomography, is notoriously difficult. Limited cooperation in pediatric patients (often driven by fear, lack of engagement, or developmental constraints) prevents ophthalmologists from obtaining the high-quality imaging necessary for accurate diagnosis. While ophthalmologists use child-friendly tools to encourage cooperation, failure of these methods often requires examinations under anesthesia, exposing young patients to the risks of general sedation. Our key insight is that transforming the Optical Coherence Tomography examination equipment into an expressive robotic character may enhance the pediatric patient experience and improve diagnostic accuracy for eye diseases. In this work, we developed a panel of character prototypes for a robotic eye examination system and presented video demonstrations of these prototypes to caregivers in clinic. Building on caregivers' insights on desired features, we establish design directions for robot characters in pediatric eye exams, using a Research through Design methodology that integrates animation theory, domain expertise, and guardian feedback.**

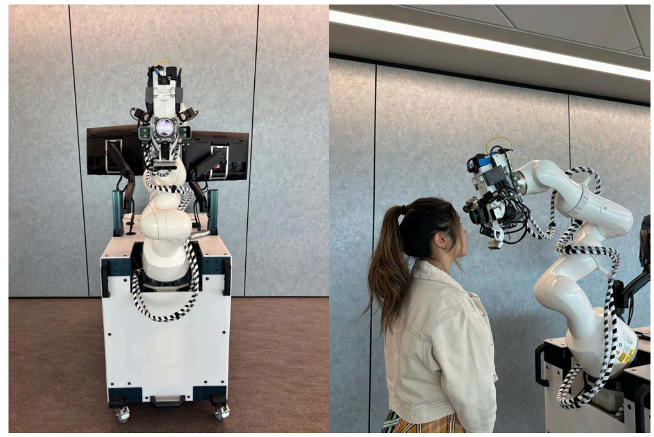

Fig. 1: Prototype OCT robot system.

I. Introduction

A small child enters the clinic, clutching their caregiver's hand. Their eyes widen as they take in the sterile room and breathe in the stinging smell of disinfectant. As the unfamiliar equipment and memory of past intrusive examinations begin to feel overwhelming, their attention is suddenly captured by a robot in a playful outfit. Step by step, the child approaches, curious as to what the robot is going to do. The robot hums softly. It knows that for this child, hospitals can be big, scary, and associated with discomfort. Its job isn't just to make today's exam efficient, but also engaging and comforting. If today's visit is a positive memory, hopefully this may make future visits easier. As the child approaches closer, the robot greets them with a gentle and encouraging voice, "Hi there! I've been waiting for you!"

Unlike adults, children may have limited understanding of medical procedures and fewer strategies of coping with heightened emotions and stress [1], [2]. Recognizing and addressing these challenges is essential to create a supportive environment promoting effective medical care and positive social experiences for young patients. Robot characters may help bridge this gap by supporting successful clinical examinations while creating engaging and less intimidating experiences for children [3]–[5]. In the past, robots deployed in medical applications have been shown to emotionally support pediatric patients by reducing anxiety and contributing to a more positive clinical experience [6], [7].

We investigate stakeholders' perceptions of character-driven robot designs in enhancing both engagement and success of clinical eye examinations. We employ a Research through Design (RtD) methodology [8] by developing a panel of robot character prototypes for a novel robotic Optical Coherence Tomography (OCT) eye imaging system (see Figure 1) [9], [10]. Through a multidisciplinary approach combining caregiver feedback, animation principles, and domain expertise from robotics and medicine, we identify key design directions for robot characters that hold potential to promote engagement, reduce anxiety, and facilitate successful pediatric eye examination experiences. The following are our research questions:

RQ 1: *What character designs are perceived to support engagement and comfort for pediatric patients in clinical eye care settings?*

RQ 2: *What design directions can be derived from integrating stakeholder feedback, animation principles, and clinical expertise?*

This work is informed by the authors' positionality in design, robotics, and ophthalmology to balance technical feasibility with medical accuracy and user experience.

II. Related Work

In this section, we review prior literature on the integration of robotics into pediatric care and animation principles towards creating believable robot characters in clinic.

A. Challenges for Children in Clinical Settings

Anxiety is one of the most prevalent emotional responses experienced by children in hospital settings, often attributed

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to being in an unfamiliar environment, separation from caregivers, and a perceived loss of control [11]–[14]. Depending on developmental stage, children may have limited cognitive and emotional capacities to process medical procedures, resulting in psychological and emotional trauma [15], [16]. Children with previous negative or painful medical exposure often experience greater anxiety in subsequent visits, making hospital visits and necessary examinations difficult for the child, their caregiver, and clinic staff [15]–[19].

OCT eye exams are non-invasive imaging tests, typically requiring the patient to sit still and focus on a target as images are taken. However, standard OCT testing can be difficult with children due to limited cooperation and difficulty remaining still, leading to poor image quality [20]. Fear of unfamiliar equipment further exacerbates these challenges, sometimes resulting in refusal from patients and caregivers. Refusal is one of the highest barriers to imaging [21], and non-compliance may lead to conducting the exam under anesthesia which has significantly higher associated risks like neuro-developmental concerns, respiratory distress, and postoperative nausea and vomiting. [22]–[24].

To mitigate this "white coat syndrome," or the fear and anxiety associated with medical settings in children, past research highlights the importance of intervention strategies such as distraction techniques, storytelling, and rapport-building between healthcare providers and young patients [25]–[28]. Robotic interventions may also utilize these intervention strategies to not only alleviate patient anxiety but also to complete procedural exams more efficiently.

B. Robots in Medical Spaces

Social robots have been developed to educate, entertain, and provide emotional support to children in healthcare settings, including those undergoing cancer treatments [29]. Researchers have also found that robotic interventions can be successful in vaccinations and compliance in rehabilitation [30], [31], even promoting joyful interactions in clinical environments, meeting the emotional needs of hospitalized children [32]. Moreover, embodied robotic systems may encourage higher engagement from pediatric patients over other mediums, such as virtual characters or traditional toys [33]. Together, these support the unique potential of robot characters as interactive tools and companions in medical contexts, transforming intimidating procedures into interactive, play-based experiences [7].

Beyond emotional and social support, technological advancements have shown how robot-assisted medical procedures, such as surgery, can make clinical procedures less invasive and more efficient [34]. These strides in advances extend to diagnostic imaging, such as OCT [9], [10], where autonomous eye-gaze and head-pose tracking enable high-fidelity imaging by adapting to patient movement – a critical advantage for pediatric populations who struggle with the rigid postural requirements of traditional exams. Children participate in the eye exam by gazing into a target inside the lens of the robot, while the mobility of the system allows for unique character moments with patients. Previous work employed patient personas to design introductory characters [35]. We expand upon prior efforts by developing a more inclusive panel of robot character prototypes informed by secondary research on children's media and extensive caregiver feedback to transform a crucial yet intimidating diagnostic tool into an engaging, child-centered experience.

C. Animation Principles for Believable Characters

How do we design these robot characters to be believable and appear life-life? *The Illusion of Life* by Disney animators Frank Thomas and Ollie Johnston is commonly referred to as the "bible" of animation and the creation of life-like characters [36]. They detail twelve principles of animation, including squash and stretch, anticipation, staging, timing, exaggeration, and appeal, which have guided Disney animators in developing emotionally engaging films. Many roboticists have turned to these animation techniques in hopes of creating more life-like robots.

Researchers have shown that 2D animation principles and workflows can be translated to the 3D physical world where robots live [37], and animation principles have been adopted to communicate emotional expression in robots that are more legible for humans to understand [38]. For instance, the squash and stretch animation principle has been used to convey the internal states of the robot [39]. Similarly, the principles of anticipation and timing have been shown to deliver more expressive movement, convey the robot's intentions, and improve the user's interpretation of the robot's actions [40], [41]. For robots to be more believable, researchers postulate that the movement should be less rigid and lean towards organic, even theatrical performances [42]. "Appeal," the last of the animation principles (yet one of the most important), can be elicited through the appearance, behavior, and movement of a robot to attract and maintain attention [43]. Thus, animation principles prove to be useful guidelines in creating robot characters, and we utilize these foundational principles in our design directions to create engaging, effective, and appropriate pediatric robot characters.

III. Robot Character Prototype Creation

Our secondary research found that children's media typically align with developmental stages through clear visuals, repetition, and simple narratives to support comprehension in younger audiences, with more complex storytelling and humor for older children [44], [45]. Relatable contexts and mission-based stories can also increase participation [44], and character alignment may impact children's trust [46]. We integrated these insights into our design process, prioritizing recognizable traits, clear goals, and purposeful narrative contexts to support engagement during the interaction.

Synthesizing our secondary research with clinical expertise in pediatric ophthalmology, we employed a RtD methodology to develop four diverse robot character prototypes (see Figure 2) for a robotic OCT system [9], [10]. Each character had a comprehensive profile with its background story, main characteristics, target demographic, interaction goals, and in-clinic user flow with the patient [47]. Descriptions of characters are as follows:

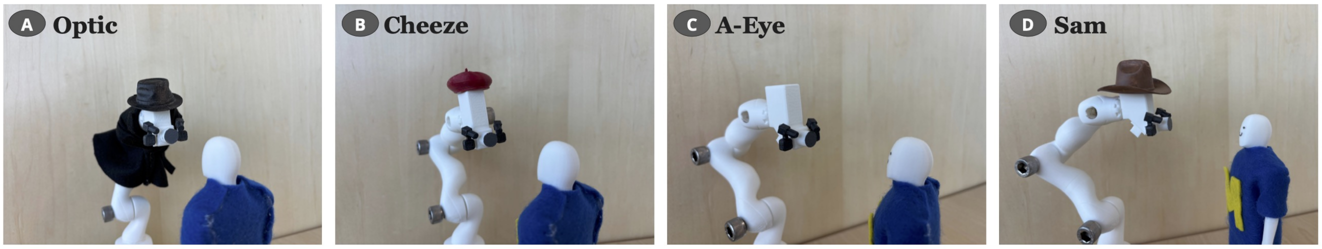

Fig. 2: Snapshots of robot character prototypes shown to caregivers. Descriptions of the characters are found in Section III.

Optic is a secret agent robot, and the patient is invited to join a special spy mission where they must pass the eye scan challenge to gain access to the secret lab. Disguised with a hat, sunglasses, and mustache, Optic makes the exam feels like a real undercover mission. Optic speaks in a quiet mysterious tone and provides reassuring guidance to make the exam less intimidating and more fun.

Cheeze is an artistic robot, recognized by its red French beret. It invites the patient to participate in a collaborative photo-shoot. Using a gentle voice to encourage the child to photograph it, Cheeze helps build familiarity and reduce the anxiety of the child. Once the patient is more comfortable, Cheeze gradually moves closer and takes a "photo" of the patient's eyes. If the exam requires more time, Cheeze keeps the patient engaged by sharing photos it has already taken.

A-Eye is a friendly robot who wants to become friends with the patient and to learn more about humans. A-Eye speaks to the patient in a playful voice and builds rapport by engaging the patient in fun games, such as a staring contest where the patient stares into its lens. These games help the patient feel less anxious and bored during the exam.

Sam is a wildlife ranger robot who wears a khaki outfit and a ranger hat. It is new the to its job at the safari park and notices that some animals who have gone missing from the park. Sam requests help from the patient to find the missing animals by looking into its lens to spot them on the screen. Sam speaks enthusiastically and provides positive reinforcement once the animals are found.

After developing the character profiles, we produced video demonstrations illustrating each step of the characters' user interaction flow in clinic with the relevant stakeholders using 3D models of the patient, guardian, and robot character prototypes (see videos at [47]). All videos contained voiceovers and captions for accessibility. Video-based methodologies have been used to evaluate robot behaviors and design concepts in early-stage research, and prior work has shown agreement between video-based and live evaluations [48]. As this study is an initial evaluation of robot characters for pediatric eye exams, all caregivers observed identical interactions in the videos, allowing controlled comparisons across prototypes before more costly in-person studies.

IV. Guardian Stakeholder Study

We recruited 30 caregivers from the Kellogg Eye Center to evaluate four robot prototypes as proxies for their children. Traditionally, caregivers serve as their child's primary decision makers and manage their engagement with different technologies, making their assessments important in evaluating the real-world adoption and suitability of robot characters. Their familiarity with their child's preferences, needs, and abilities further enables them to determine the potential fit and acceptability of each prototype to support appropriate pediatric user experiences. Our survey took about 15 minutes to complete, and $20 was given as compensation. This study was approved by the University of Michigan Institutional Review Board #HUM00264759.

Caregivers first responded to psychographics about their child such as personality traits and also prior experience with OCT exams. Following this, they progressed to the experimental portion of the study where they were shown video demonstrations of two robot character prototypes, which were randomly selected and balanced to ensure equal pairings of characters. After each video, we collected qualitative data through open-ended questions (see [47]) regarding their child's projected experience with the robot, effectiveness of the character's story and appearance, additional features desired on the robot, potential problems, and how the character could further improve the exam experience. Caregivers also indicated their preferred character, suggested other characters to consider, reflected on robotic OCT compared to traditional OCT, and provided final comments before finishing the study.

V. Results

We applied an inductive thematic analysis to the data obtained from the caregiver stakeholder study where themes and categories emerged from the data rather than being predefined [49]. The first coder analyzed the full dataset and developed an initial coding structure. A second coder then independently analyzed the entire dataset with access to the initial codes, refining and clarifying themes and categories where interpretations were ambiguous. The final codebook can be found in [47] which includes a visual layout of the theme groupings. This paper focuses on the qualitative analysis, and the quantitative results can be found here [50]. From our final codebook, several reoccurring themes emerged, which we discuss below.

A. Visual Appearance

A playful aesthetic and point of interest can capture attention and promote engagement. Many caregivers appreciated the playful costumes and highlighted the visual points of the characters when asked about how their child would respond to the robot. Cheeze, who wears a red beret, received the following feedback, "It's funny that it's a robot wearing a french hat" (P17) and "Cheeze looks fun, the hat. Curious to what this character is going to do" (P2). Sam, wearing a brown ranger hat, received many comments such as "[the] hat was the selling point" (P27) and "I liked the hat... gives it more personality" (P13). Optic, with a black detective hat and trenchcoat, also received positive feedback saying, "I think the hat, coat over the robot disguised it and it was cool... It did feel like a secret mission" (P19) and "There isn't anything I would change. I like the cartoonish spy outfit of the trenchcoat and the hat" (P14). These playful visual points of interest may help grab children's attention and build curiosity from the initial exposure to the character.

Visual anchors for persona contribute to the appeal of the character and comprehension of the character's story. Guardians expressed interest in more accessories or visual points that could be added to simple character costumes. One guardian said, "Not enough to look at (Sam), brown coat would help to give it more of a look. A star on the coat or a badge" (P8), while another responded, "I would add maybe a red coat to match with [Cheeze]. I don't like the all white part" (P30). Most caregivers believed Optic, with a full secret agent costume, had the "proper getup" (P15), while others thought it could be improved by "[putting] eyes or detective badge/lanyard that agents have" (P22). A-Eye received mixed commentary concerning its plain outward form. Some caregivers expressed positive feelings regarding the minimalist look reporting, "I like the outward design and the fact that it looks like a robot" (P12) while others said, "It looked like the machine – did not like that... Most children are scared of normal machines here at clinic" (P7).

Color is visually compelling and acts as an affective primer. Color was a commonly repeated theme in the outward appearance of the character, and many guardians mentioned that more bright colors could help to engage their child. One guardian said, "Add more colors to [A-Eye] – make the child feel more comfortable" (P22). Another guardian said, "The kids love color – a way to make [Sam] a little more colorful" (P16). These requests for more color on the character may not only help to grab the child's attention, but also move away from the negative associations with sterile, monochromatic medical spaces.

Familiar features can bridge the gap between a scary machine/examination to friendly robot companion. Integrating familiarity into the character interaction was frequently discussed, specifically in the outward appearance. Anthropomorphic features like eyes, limbs, and facial hair were desired by caregivers. For instance, caregivers responded, "Maybe better if there was googley eyes on [Optic] – more anthropomorphic" (P1), "paper mache arms; arms that have some kind of movement" (P15), "I would add a mustache – a French, curly mustache (Cheeze)" (P14). Familiar features may serve to create a more believable and approachable character that increases the child's comfort during the interaction.

B. Character Story Engagement

The character's story should be approachable, age-appropriate, and empowering. Many caregivers mentioned friendliness and understanding as integral traits of the character and its story. When speaking about A-Eye and its story of befriending and playing a game with the child, one guardian stated, "[My child] would like the idea of having a robot friend and seeing how the robot works and what it does. He would be very curious and ask a lot of questions" (P26). Another caregiver commented on Sam and Cheeze's stories saying, "Kids are able to understand 'find the animal' and 'taking photos'; generic and kid-appropriate (can be customizable to the child's age)" (P13). Having a sense of control over the interaction or exam was also mentioned by several guardians, stating, "Kids taking photos first gives them more control over a situation where they feel like they have no control over" (P13).

Incorporating amusement, playfulness, and fun can draw children's attention and maintain engagement. Fun and playfulness were often brought up when asked about the characters' stories. The guardians' responses largely echoed these sentiments: "[A-Eye's] story and playing the game is fun" (P22), "[Optic's] pretty creative; gets the kid's attention more and they will think it's fun and will make it a more positive experience" (P6), and "I like the photo-shoot before (Cheeze), sounds very fun to do. I feel like this is a really fun experience compared to going to the doctor's office" (P14).

C. Character Movement

Movement should not scare or interfere with the medical procedure. The majority of the caretakers expressed a desire for the robot character to have little to no movement due to the need to keep still for clear imaging and prevent distraction. One guardian stated, "No movement; you would need the child to sit still so too much movement would create interruptions" (P11), and another said, "Movements might scare the little kids if they haven't seen any robots" (P6). However, acceptable movement that would add to the character and make the intervention more interactive and fun were mentioned. One guardian replied, "It could wave and could dance. Fun movements to make it less scary" (P26). Another said, "I want it to bend down and wiggle" (P24).

D. Character Communication

The robot should clearly communicate every part of the interaction to reduce patient confusion and offer reassurance. Clear communication was a highly desired feature, especially in a medical setting where many children face anxiety towards sensitive and intimate examinations. Many guardians wanted the robot to "walk the kid through what's about to happen" (P9) and to "[speak] about what they're going to do" (P24). Some also mentioned that the robot would "speak positively to them after finding the animal (Sam)" (P7) to provide positive reinforcement and association for the child.

E. Active Engagement

Gamification can promote and maintain engagement during the examination. Guardians liked the gamification aspect to help make the exam more engaging and interactive for their child. "I liked how when you look into the robot (A-Eye), it's a game – staring contest – lets the kids think it's more of a game than an appointment. More fun" (P12).

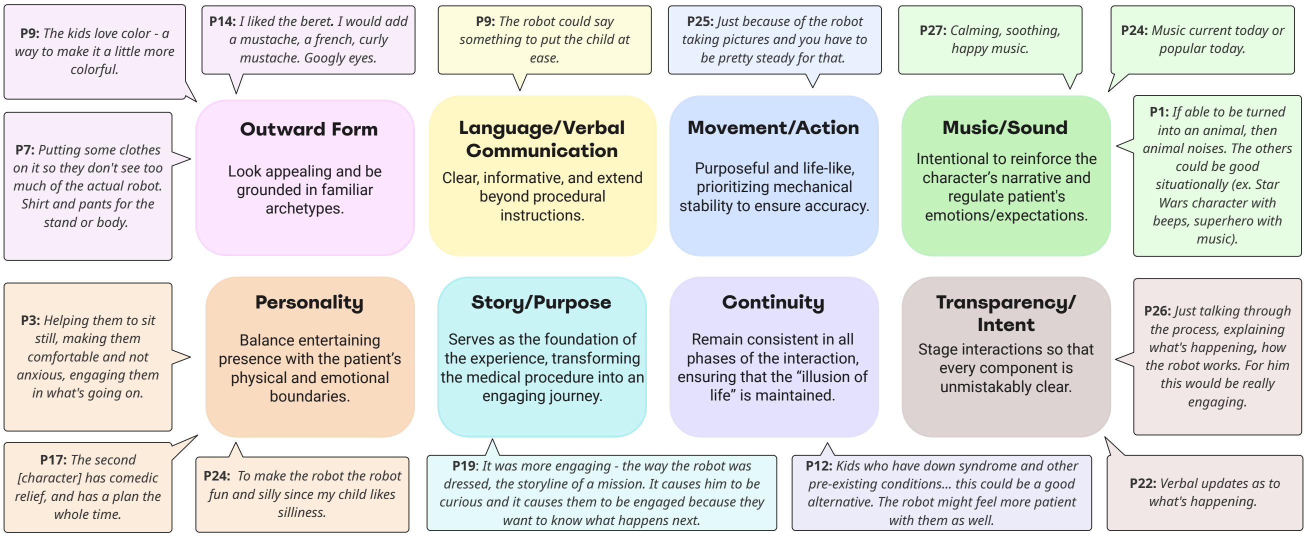

Fig. 3: Design directions for pediatric robot characters (VI). These design directions are grounded by principles in animation; domain expertise in robotics, HRI design, and medicine; and guardian stakeholder feedback in clinic.

Another said, "Children like finding animals and feel like they're accomplishing things – gamifying (Sam)" (P13). Inclusion and interaction during the examination process can provide a sense of accomplishment and purpose to the child, and help to distract and reduce anxiety.

VI. Design Directions

We synthesized insights from our guardian study with animation theory and domain expertise to establish design directions for believable robot characters in pediatric eye exams. This triangulation balances technical feasibility with the engagement and medical professionalism required for clinical trust. The italicized questions serve as internal prompts for design and research teams to guide reflection and decision-making throughout character development.

1) Visual Appearance: **The robot should look appealing and be grounded in familiar archetypes.** *How do costume, recognizable features, and color, work together to create a character that encourages curiosity and play, while reducing the "white coat" anxiety of medical hardware and exams?*

As animation theory emphasizes, characters should have "appeal" with qualities such as charm, pleasing design, and magnetism [36]. A playful aesthetic and visual point of interest as part of the costume and accessories were highly discussed by guardians as a method to capture and maintain attention, while familiar features such as anthropomorphic leaning preferences (e.g., googly eyes, limbs, mustache, etc.) may elicit more comfort with the robot character, promoting acceptance and continued engagement. Character personality often begins with color [36], and guardian requests for more colorful characters supports this idea.

2) Language/Verbal Communication: **The robot's communication should be clear, informative, and extend beyond procedural instructions.** *Can easy-to-understand terminology, playful inquiry, and inclusion of non-medical dialogue be implemented to create an engaging and warm social experience?*

In clinical training, avoiding the "objectification" of the patient is crucial. Physicians are taught to maintain verbal engagement, use age-appropriate terminology, and discuss topics beyond the immediate procedure to build rapport [51]. Our findings confirm that caregivers prioritize these same qualities and view them as essential to mitigate stress and anxiety. By integrating these behaviors into robot character prototypes, human-centric "bedside manners" are translated, ensuring the robot possesses an engaging presence rather than being purely a mechanical examiner.

3) Movement/Action: **The robot's movement should be purposeful and life-like, prioritizing mechanical stability during the examination to ensure clinical accuracy.** *How can timing, synchronization of action with speech, and interactive movements work together to balance playful immersion with medical accuracy?*

Movement is crucial to conveying life-like qualities in robots or creating believable characters, and timing alongside other expressive modules, such as speech, can allow for greater expression of character [36], [52], [53]. However, many caregivers expressed that movements of the robot should not be sudden or unexpected to not scare patients. Therefore, the robot's movement should be balanced to include these considerations and actions necessary to carry out the exam while conveying the character's personality.

4) Sound Effects/Music: **The robot's auditory output should be intentional, using music and sound effects to reinforce the character's narrative and help regulate the patient's emotions and expectations.** *What types of music and task-specific audio work together to create an immersive atmosphere?*

Music is a "vital element in making fantasy world believable" [36], and many guardians requested that music be integrated into the interaction. Caregivers stated that the audio experience may contribute to the experience during the exam (e.g., calming, upbeat, trending kids music to invoke familiarity), and sounds should match the character interaction task (e.g., animal noises to match the animals on the screen). The audio output should elicit a multi-sensory experience, balancing the patient's emotional comfort, strengthening the character's storyline, and keeping task-oriented focus.

5) Personality: **The robot's personality should balance a lighthearted, entertaining presence with respect for the patient's physical and emotional boundaries.** *How can a friendly, approachable demeanor – blended with moments of silliness and fun – coexist with clinical professionalism to ensure the patient feels in control throughout the interaction?*

In a medical environment, caregivers stressed the importance of the robot character having an approachable and friendly personality. Many guardians mentioned the "fun" that robot characters offer over the traditional medical examination and equipment, and how they can build rapport with the patient to relieve anxiety. In animation, the pictures that elicited the greatest audience responses had definite stories and rich personalities [36]. However, the robot functions as a medical professional as well, and it must be respectful of the patient, especially those with previous trauma associated with medical settings [54] – the robot should pull away when the patient does not want to continue or allow the patient to feel in control during the interaction.

6) Story/Purpose: **The robot's story narrative should serve as the foundation for the experience, transforming the medical procedure into an engaging journey.** *How can a clear, understandable purpose – driven by curiosity and subtle gamification – maintain patient engagement and focus without becoming overstimulating?*

The robot's story should incite curiosity, and the patient should not be able to predict everything that is about to happen in order to maintain their attention. To encourage this sense of curiosity and engagement, gamification is a helpful element that can also provide a sense of accomplishment when the patient completes a task with the robot character. In concordance with principles in children's media and medical practices, the storytelling should be understandable and interesting at the patient's age and mental capacity.

7) Continuity: **The robot should remain consistent across the entire interaction, ensuring that the "illusion of life" is maintained, even during technical troubleshooting and patient interruptions.** *How can the character prevent "breaking character" (commonly expressed as "breaking the fourth wall" in theatre [55]) for a seamless patient experience?*

Even in transition moments, technical troubleshooting, and patient difficulty, the character's life-like qualities must persist. For a child in a hospital, a robot that suddenly "shuts off" or reverts to a cold, mechanical state can be jarring and break the relationship already established. For instance, idle movement and behaviors can help reduce surprise once the robot comes back online [52]. Therefore, designers should account for deviations from during the interaction to ensure that the robot always remains "in character."

8) Transparency/Intent: **The robot's interactions should be staged so that every phase of the interaction is unmistakably clear.** *How can constant communication and the signaling of upcoming actions be incorporated for transparency and proper framing of the procedure as a safe, inclusive, and intentional event?*

In animation, staging is a "presentation of any idea so that it is completely and unmistakably clear" [36]. Caregivers value transparency and physicians practice providing their intent in every interaction related to a medical exam. Constant and clear communication at every point of the interaction and involving the patient is crucial to ensure that the patient feels comfortable and at ease [51]. Robot characters should follow these same guidelines to ensure that the patient understands what is happening at any stage of their interaction.

VII. Conclusion

Through guardian feedback, domain expertise, and animation principles, we derived design directions for the outward appearance, communication, movement, sound, personality, narrative, continuity, and transparency to create fun, effective, and appropriate robot characters for pediatric eye examination experiences. This study is an initial evaluation of robot characters with caregivers, and future work will focus on pediatric perspectives to the embodied robot OCT character prototypes in clinic to confirm children's preferences, comfort, and engagement during the interaction.

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