"Are you smart?": Children's Understanding of "Smart" Technologies

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ABSTRACT

Although children are increasingly using smart technology, there is limited knowledge on what children define as "smart" for technology. Understanding what children expect as "smart" would ensure more effective positive experiences with smart devices. To investigate children's expectations, we conducted five participatory design sessions with 10 children focused on designing smart technology. The children also interacted with four commercial smart devices (i.e., robot, AR headset, voice assistant, tablet with AR applications) and judged them on intelligence. We found that children expect smart technologies to have advanced intelligence, human-like characteristics, immersive experiences, and serve multiple purposes. Furthermore, children thought smart devices should be difficult and complex to make. We also observed negative interactions with current smart devices, such as physical device limitations. The insights gained from this study can inform the design and development of future smart technology devices, ensuring they are engaging and aligned with children's needs and preferences.

CCS CONCEPTS

• **Human-centered computing**;; • **Human computer interaction (HCI)** → HCI theory, concepts and models;

KEYWORDS

Smart technology, children, co-design, participatory design, augmented reality, robot

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1 INTRODUCTION

Children are increasingly using smart technology, such as voice assistants [30, 32, 59], robots [5, 7, 17, 45], AR headsets [50], AR applications in mobile devices [13, 40], smartwatches [11, 57], and smartphones [13, 20, 60]. These devices are being utilized for a wide range of purposes, including education [9, 26, 35] and entertainment [28, 45]. Smart devices are commonly used for entertainment for children, offering platforms for games and interactive experiences that foster creativity and enjoyment [58]. For instance, AR applications, like Pokémon GO [13], are continuing to increase in popularity. In Pokémon GO, players use their smartphones to detect, capture, and collect virtual Pokémon that appear in real-life locations. Research in educational technology has explored the impact of smart devices on enhancing learning experiences for children [9, 29, 35]. For example, using a smart watch to personalize learning experiences by tracking school students' engagement levels, providing real-time feedback, and offering adaptive educational content based on individual needs [29]. However, there exists a gap in our understanding of how children perceive and define "smart" in smart devices. Understanding children's perceptions of "smart" technology is crucial for tailoring designs to children's needs and preferences. Previous research has shown that children's expectations and interactions are different than adults for a range of different devices (e.g., AR headsets [50], mobile devices [3, 20]), which can lead to usability issues. According to the Expectation-Confirmation Model for information systems, users are more satisfied with a system when they view it as useful and when their expectations are met [6]. If expectations are not met, usability issues can occur causing errors and frustration [15]. As more children start to utilize these commercially available devices, it is important to examine these smart devices with children, aiming to understand their perceptions of "smart" technology and gain insights into their interactions.

To gain insight into how children perceive and interact with "smart" technology, we conducted five participatory design (PD) sessions. PD engages children in the design process while helping to elicit rich ideas from them [4, 49] and can be used to construct children's mental models [51]. Modeling children's thought processes is important to capture how children perceive things and has been used to develop children's learning instruction and technology (e.g., [19, 48]). Our PD sessions involved 10 children, between the ages of 7 and 12; during these sessions, we examined how children conceptualize "smart" in smart devices through having the children: (1) design their own smart technology using craft materials, (2) interact with four commercially available smart devices: a social robot (i.e., Miko [63]), Magic Leap 2 AR Headset [64], Amazon Echo (i.e., Alexa [65]), and a Samsung Galaxy A8 tablet [66] with AR applications [67, 68], and (3) judge the intelligence of these four commercial devices. By including these commercial devices, we aimed to fully understand the factors influencing children's judgments on the intelligence of current technologies. Each device was carefully chosen for its distinct capabilities: immersive experiences and user mobility (AR headset, tablet with AR applications), device mobility (Miko), visual screen (Miko, tablet with AR applications), speech, games, and informational features (Alexa, Miko), and ability to foster collaborative interactions (Alexa, Miko, tablet with AR applications). Also, all chosen devices are commercially available, ensuring relevance to real-world scenarios.

After completing the PD sessions, we created an affinity diagram to analyze the children's utterances from the video recordings of the sessions and determine the main themes in how children conceptualize "smart" devices [6]. We found that children expect smart technologies to have advanced intelligence, human-like characteristics, immersive experiences, and serve multiple purposes. Specifically, children expect advanced intelligence in smart devices, such as self-recognition, user awareness, environmental understanding, and emotion comprehension, as well as human-like characteristics, including friendship and physical characteristics (e.g., heart and brain). Additionally, children perceive smart devices as more intelligent when they view them as more difficult and complex to make. Furthermore, we observed children's negative interactions with current smart devices, showing challenges related to physical limitations. The contributions of our work include: (1) insights into how children perceive "smart" in smart devices, (2) observations on children's challenges with current smart devices, and (3) new recommendations on designing future smart devices that match children's expectations. Our insights can inform the design and development of future smart technology devices, ensuring they are aligned with children's needs and preferences.

2 RELATED WORK

In our review of prior work, we concentrate on four key areas of research: (1) children's perceptions of smart technology; (2) children's interactions with smart technology; (3) the definition of smart technology; and (4) participatory design (PD) methods. There is a broad spectrum of smart technology, encompassing various device types; however, due to the paper length constraint and to maintain focus, we mainly concentrate on the four commercial smart devices the children interacted with in our study: a robot, AR headset, voice assistant, and a tablet with AR applications.

2.1 Perception of Smart Technology

In our review of prior research on children's perceptions of smart technology, including robots [8, 9, 17, 42, 47, 61], voice assistants [22, 24, 32, 37, 59], and AR devices [1, 2, 10, 36, 44, 50, 53], we discovered a comprehensive understanding that encompasses both positive and negative perspectives. In the exploration of child-robot interactions, Cagiltay et al. [9] conducted a study focusing on the potential of children (ages 8-12) to actively partake in caretaking activities with social robots. The study, facilitated through an exploratory design session, illustrates how children actively engage in nurturing behaviors towards social robots. The findings suggest that these interactions, ranging from feeding the robot to teaching it, go beyond functional utility, they foster meaningful connections like friendships. Druga et al. [17] examined how children (ages 4-10) and parents assess the intelligence of mice, robots, and themselves in a maze-solving activity. Most of the participants believed that the robot was smarter than the mouse. Yip et al. [61] conducted four PD sessions with children (ages 7-11) to explore their perceptions of "creepy" technologies. The authors highlighted positive aspects such as companionship, educational support, and entertainment, but they also noted children's multifaceted views on robots, considering factors contributing to the perception of creepiness. They identified concerns about a robot's physical appearance, lack of control over its actions, and the discomfort associated with a robot's agency and independent behavior. Rubegni et al. [42] investigated children's (aged 8-14) perceptions of social robots using ten fictional scenarios. The study revealed negative concerns beyond creepiness, encompassing fear of robots being perceived as "bad" and questions about accountability.

In examining voice assistants (VAs), Xu and Warschauer [59] delved into the perceptions of children (ages 3-6) interacting with VAs, such as those found in smart speakers or smartphones. Children demonstrated mixed perceptions, attributing both artifact and animate properties to VAs. When considering the animate properties of VAs, children often observed that VAs could respond intelligently to their questions, hold conversations, and even display emotions in their interactions, attributing cognitive abilities and emotional responses to them. On the other hand, in perceiving VAs as artifacts, children focused on the physical characteristics and functional aspects of these devices. In a study on families' use of Google Home, Garg and Sengupta [22] interviewed 18 families to explore their perceptions of VAs. Despite the absence of human-like features, children often probed the device with identity-related questions (e.g., *"When were you born?"*). Younger children (ages 5-7) ascribed human-like attributes to Google Home, believing it had feelings and thoughts. However, older children (ages 7-15) engaged in more playful interactions, testing the device's limitations.

Woodward et al. [50] conducted online PD sessions with children (ages 7-12) to explore their perceptions of AR headsets. The findings revealed that children perceive AR headsets as highly intelligent systems capable of recognizing and transforming their surroundings, providing an immersive experience. Interestingly, the children viewed AR headsets more as tools for specific situations rather than pervasive elements in daily life. Cassidy et al. [10] utilized PD methods to gain insight into what augmentations children find engaging in play contexts. The children (ages 7 and 8) were instructed to create designs for a "super pair of glasses" that would help them play. The most common elements the children added were item information and instructions. Similarly, Sim et al. [44] used PD methods to examine how children would design AR experiences for a museum context. The children (ages 7-9) were presented with a storyboard of going to a museum, putting on smart glasses, and looking at an exhibit of a Roman soldier. The authors found that the children were able to grasp the idea of AR and proceeded to design virtual content, such as fighting the soldier.

In addition, researchers have also explored children's perceptions of comparing smart technologies. Druga et al. [16] investigated how children (ages 3-10) perceive different technologies by studying how they interacted with VAs (i.e., Alexa, Google Home), a robot (i.e., Cozmo), and a chatbot (i.e., Julie). The children played with the devices and then answered questions on trust, intelligence, personality, and engagement. Overall, the children found the devices friendly and trustworthy, and they wanted mobile and responsive devices that could have engaging conservations.

Overall, prior work has examined children's perceptions of a range of smart devices (e.g., robots, AR devices). However, most of these studies have not explored what children consider as "smart" when it comes to technology. Also, most of these prior studies tend to focus on a single device, (e.g., only an AR headset), rather than comparing how children perceive different smart technologies. Druga et al. [16] compared multiple devices and examined intelligence, but the authors focused more on conversational agents and on children's interactions. Our goal is to go beyond prior work by including more of a range of smart devices, including ones with immersive capabilities, and by implementing in-depth participatory design sessions.

2.2 Interaction with Smart Technologies

Previous studies have explored children's interactions with various smart technologies. For instance, Michaelis and Mutlu [35] conducted a study examining how children (ages 10-12) interact with a learning-companion robot named Minnie. In a two-week field study, children participated in activities guided either by Minnie or traditional learning methods. Children reported positive experiences with Minnie, such as maintaining sustained engagement.

Prior work has examined children's interactions with AR devices [10, 13, 39, 56]. Radu et al. [39] conducted a comprehensive study to unravel how children (ages 5-10) interact with handheld AR technology, specifically exploring selection techniques such as crosshair and finger selection. The study revealed that children exhibited diverse selection times, tracking losses, and recovery times, emphasizing the multifaceted nature of AR performance. Munsinger and Quarles [36] conducted an in-depth exploration of children's (ages 9-11) interaction with AR headsets. The study examined three interaction approaches: voice recognition, gesture recognition, and controller during a confirmation task on the AR headset. The researchers discovered that controller selection was faster than both voice and gesture. Woodward and Ruiz [53] examined how different textual designs in an AR headset affect children's (ages 9 to 12) task performance. The research highlighted a significant impact of textual information location on task performance. Specifically, when the information was placed in the main direction the children were looking at, it led to higher information recall accuracy.

Other studies have also examined how children interact with voice assistants (VAs) [30, 32, 59]. Lovato and Piper [32] examined how young children use voice input systems by analyzing YouTube videos of children using Siri and conducting an online survey of parents. They identified three primary ways children use voice input systems: exploration (e.g., trying to understand the system), information seeking (e.g., asking questions), and function (e.g., trying to operate the device). Kim et al. [24] conducted a study on how children (ages 5 to 10) interact with a VA, and they found that the device only responded appropriately to the children's speech half of the time.

While existing research has explored various aspects of children's interaction with technology, there remains a significant gap in understanding how children conceptualize and define "smart" technology. Our research contributes to this area by conducting participatory design sessions and examining children's interactions and perceptions of current commercial smart devices.

2.3 Definition of Smart Technology

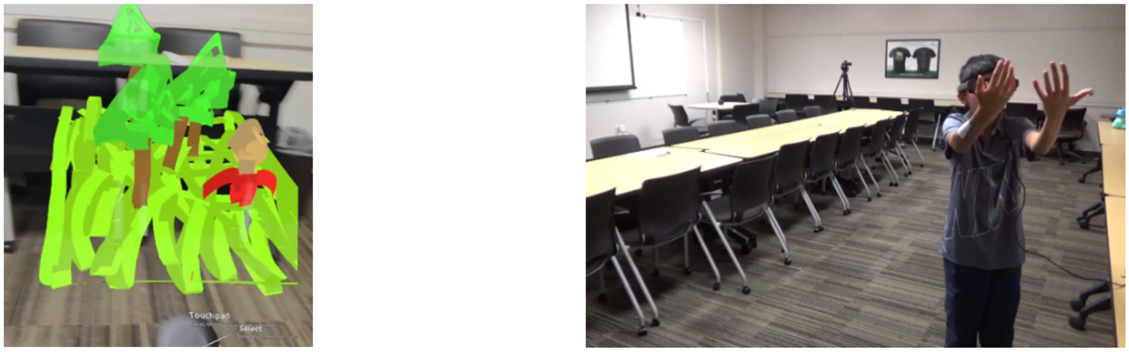
The term "smart" is defined as "having or showing a high degree of mental ability" [69]. "Smart" has since then evolved significantly within the context of technology, particularly due to the rise of smart technologies across various fields [12]. Prior work has defined smart technology as physical/digital objects that include sensing, processing, and network capabilities, which enables them to interact and respond immediately to changes in the external environment [27, 46]. These tangible objects have the capability to sense, understand and respond to events and human activities in the physical world, resulting in an interactive technology that shares data and engages with its users [34, 41]. While existing research has delved into how children interact with and perceive different smart technologies, there are still open questions about how children think about "smart" technology.

2.4 Participatory Design

For our study, we used participatory design (PD), which is a method that facilitates collaboration between users and designers in the technology design process, allowing for the co-creation of new technologies [50]. PD methods have been used in prior studies to involve children in the process of creating technology [10, 18, 23, 24, 49, 51, 52, 62]. PD can elicit rich ideas from children, more so than interviews [4, 14, 52]. For our PD techniques, we chose to use *Big Paper*, *Bags of Stuff*, and *Line Judging* [49] (more details on these techniques in Methodology). Our focus is on understanding children's perceptions of smart technology and how children naturally interact with these devices.

3 METHODOLOGY

In our study, we conducted five separate participatory design sessions involving children (ages 7-12). Each design session was 120 minutes and was broken down into three main parts: (1) design a smart technology, (2) interact with four commercial smart technology devices, and (3) judge the four devices based on intelligence. We aimed to explore and understand children's perspectives on



(A) (B)

Figure 1: (A) A child participant's drawing from the Leap Brush application in the Magic Leap 2 AR Headset. (B) Child participant interacting with the Hand Tracking application in the Magic Leap 2 AR Headset.

what constitutes "smart" technology (i.e., what is "smart"). The study was conducted in a spacious room and the children were compensated with a small prize (e.g., bouncy balls, stickers). All design sessions were audio and video recorded. Our research protocol was approved by our Institutional Review Board, and we collected both parental consent and child assent.

3.1 Design Session

Each participatory design session was 120 minutes and divided into six parts: consent and introductions (15 minutes), design activity (20 minutes), design activity discussion (15 minutes), device interaction (40 minutes), judge activity (15 minutes), and debrief and compensation (5 minutes). We also included time for breaks.

3.1.1 Design Activity. In the design activity, the children were asked to use craft materials to create their own smart technology. The focus of the design activity was to understand what elements the children expect in "smart" technology. The children were instructed to "*create and brainstorm anything that you would like, it just has to be smart.*" We utilized the participatory design techniques *Bags of Stuff* and *Big Paper* [49]. *Bags of Stuff* is a low-tech prototyping technique, in which large bags are filled with craft materials (e.g., construction paper, googly eyes, etc.) and the participants use the materials to create a low-fidelity prototype. *Big Paper* is a form of paper prototyping, in which the participants have a large piece of paper to collaborate and draw. After the design activity, everyone regrouped to discuss their finished designs.

3.1.2 Device Interaction. Following the design activity, the children were divided into groups to freely interact with four commercial smart devices placed around the room. The children interacted with each device for 10 minutes before switching to another device, for a total of 40 minutes. The devices included a social robot (i.e., Miko), a Magic Leap 2 AR Headset, a tablet with AR applications, and an Amazon Echo (i.e., Alexa). As mentioned before, we chose these four devices to get a range of capabilities: immersive experiences and user mobility (AR headset, tablet with AR applications), device mobility (Miko), visual screen (Miko, tablet with AR applications), speech, games, and informational features (Alexa, Miko), and collaborative interactions (Alexa, Miko, tablet with AR applications). In addition, all four devices fit the definition of smart technology as discussed in the Related Work section. We observed and recorded the children's interactions with the devices to capture how they interact and think about current commercial smart technologies. We allowed the children to freely interact with the devices to examine their natural interactions. For the AR headset and tablet, while the children still freely interacted with the devices, we provided specific commercial AR applications. We utilized the provided demo applications for the Magic Leap 2: *Leap Brush* [70] and *Hand Tracking* [71]. We selected *Leap Brush* and *Hand Tracking* because we wanted to ensure an engaging and interactive experience for the children in our study. *Leap Brush* allows users to draw and manipulate virtual elements over the real-world using an external controller (Figure 1A), while *Hand Tracking* allows users to see virtual hands overlayed over their own hands that would mimic their movements in real-time (Figure 1B). We started by allowing the children to use *Hand Tracking* in order to see and get a feel for the virtual aspect in AR for a few minutes, then switched to *The Leap Brush* for the rest of the interaction. For the tablet with the AR applications, we utilized the Samsung Galaxy A8. We provided two applications: *ARLOOPA: AR Camera 3D Scanner* [68] and *Mission to Mars AR* [67]. We chose these two applications after doing a quick systematic review of the Google Play Store. We searched the Google Play Store using keywords such as "AR children interaction", "AR interactive learning", and "AR App for Learning". Our criteria included selecting free apps with a 4.0 or higher rating to ensure a positive user experience. *Mission to Mars AR* and *ARLOOPA* met the criteria, and both were rated for ages 4+. *Mission to Mars AR* lets users take an up-close look at Mars and the rovers that have been on Mars, while *ARLOOPA* allows users to view different virtual elements in the real world (e.g., animals, cars, etc.).

3.1.3 Judge Activity. After interacting with the four devices, the children then rated how smart they thought each device was. We utilized the participatory design technique *Line Judging* [49]. The

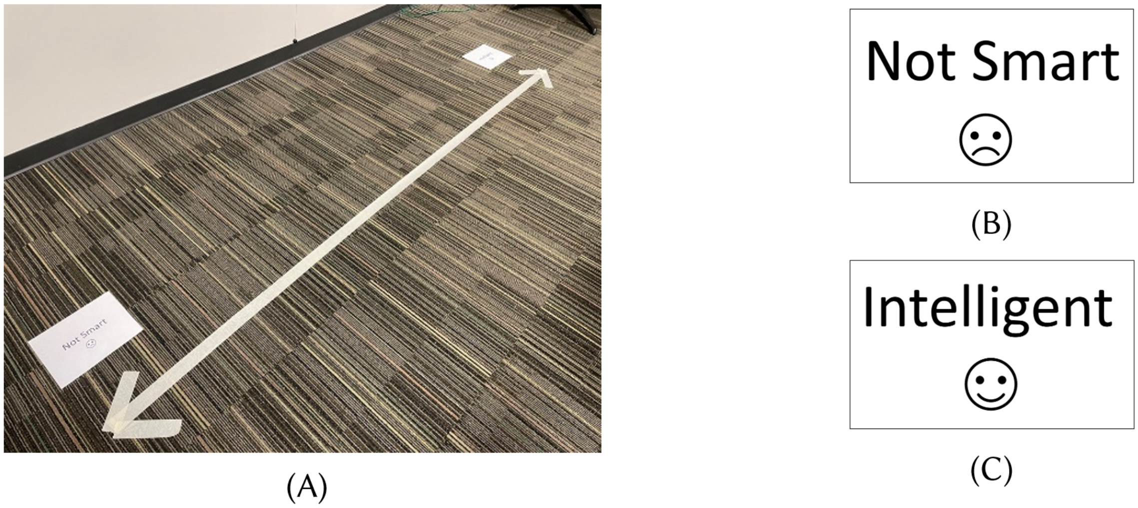


Figure 2: Judge Activity (A). Arrow used for the Line Judging for the children to stand on. (B). The "Not Smart" sign placed on the left end of the arrow. (C) The "Intelligent" sign placed on the right end of the arrow.

line judging activity provided an immediate reflection of the children's perceptions and judgments regarding the intelligence of the commercial devices. We made a 10-foot arrow on the floor using tape, with the left end representing "not smart" and the right end representing "intelligent" (Figure 2). The children positioned themselves along the arrow on the floor, based on how smart they perceived each device to be. We then asked them their opinions and the reasoning for their rating.

3.2 Participants

The study involved 10 children between the ages of 7 and 12 (M = 10.2, SD =1.5), 5 females and 5 males. The children's grade levels spanned from second grade to seventh grade (Table 1). We recruited children ages 7 to 12 as it is consistent with previous participatory design sessions with children [24, 50, 52, 62], as well as prior work that has analyzed children's interaction behaviors with smart devices [17, 25, 51]. None of the children self-reported any previous interaction with an AR headset or Miko, but all the children self-reported having prior experience with Alexa and AR tablet applications. During design sessions 3 and 4 (Table 1), multiple children signed up but not all attended. Although only one child was present, we proceeded with the session. In all the design sessions the researchers actively designed and participated with the children (e.g., playing with Miko together).

3.3 Data Analysis

The data collected from the participatory design sessions included the audio and video recordings of the design activities, device interactions, and the judging activity, as well as the physical designs from the design activity. We transcribed the audio and video recordings using Descript [72], an online transcription tool. The video recordings included approximately 524 minutes of video data. The transcriptions resulted in 991 utterances used for analysis (i.e., excluding utterances not pertaining to the design activities). Out of the 991 utterances, 655 were made by children (66%); the rest were made by adult researchers. Similar to prior work [52], we analyzed the utterances through affinity diagramming, which is a method to organize largescale qualitative data through a bottom-up inductive approach [6]. We did not compute inter-rater reliability as it is not recommended when the research goal is to determine concepts and themes [33]. To create the affinity diagram, we iteratively grouped the individual utterances into themes over the course of 18 meetings (approximately 24 hours) using Lucidchart [73], an online whiteboard tool for remote collaboration. The affinity diagram allowed us to identify recurring themes and patterns regarding the children's expectations, preferences, and reflections on smart technology.

4 RESULTS

We split the results into two categories: the children's perceptions of what constitutes "smart", and the children's interactions and rated intelligence with the commercial smart devices.

4.1 Perceptions of "Smart" Technology

In examining the children's designs from the design activity, we identified 5 main groups: *Device Abilities*, *Device Physical Properties, Context of Use, Human Characteristics*, and *Immersive Capabilities*. We will now discuss each of the groups and themes, with examples from our design sessions.

4.1.1 Device Abilities. In *Device Abilities*, we found that the children expected smart technology to be able to *Recognize Speech (input/output), Move and Allow Mobility*, *See and Sense*, *Connect with Additional Devices*, and *Shapeshift*. Throughout the design sessions, the children explored and discussed different device abilities like smart technologies that could respond to voice commands, move autonomously, connect with other devices, sense/see their surroundings, and even shapeshift for different purposes. The children frequently integrated speech capabilities, both input and output, in the smart devices. One example from P8 (10-year-old female)

Table 1: Child Participant Demographics.

Child Participant Number	Age	Gender	Grade Level	Design Session Number
P1	12	Male	7	1
P2	7	Female	2	1
P3	11	Male	6	1
P4	11	Male	7	2
P5	11	Male	4	2
P6	9	Female	6	2
P7	12	Female	7	3
P8	10	Female	5	4
P9	9	Male	4	5
P10	10	Female	5	5

included an idea of a Polaroid camera that acts as a mini assistant and takes pictures for you (Figure 3E): "*It [polaroid camera], it could listen to your conversation. What, what you're saying you want the picture to be like.*" P8 extended the concept by proposing that the camera could provide verbal cues such as "smile" when taking a solo picture or suggesting a random word to capture the picture. P8 wanted her device to include personalized engagement and response to commands. In addition, P7 (12-year-old female) designed an action figure that could listen and talk to you. P7 also compared her device to Alexa, suggesting it could provide answers.

The theme of *Move and Allow Mobility* emerged as the children designed smart technologies capable of dynamic movement. P1 (12-year-old male) created a ball that could move autonomously (Figure 3A): *"And this is a ball. And if it gets like, maybe like it gets over a fence, like it will come back to you. You don't have to go get it."* P1 expected the ball to be able to sense the user and environment (*See and Sense*), in order for the ball to come back to the user when lost. The children frequently expected smart devices to recognize the user, the environment, and itself. The action figure designed by P7 had capabilities that would recognize if the user was not listening to their parents: *"then like the, the screen will shut off immediately."* For *Connect with Additional Devices,* the children envisioned smart technologies seamlessly connecting with other devices to have a broader technological ecosystem. For instance, P9 (nine-year-old male) designed smart glasses that could connect to Siri and YouTube. Finally, we observed the theme of *Shapeshifting.* When P8 designed the Polaroid mini assistant, she discussed the camera as a little friend capable of shapeshifting into different things and reading your mind. According to P8, "*...it's like your little, your little friend, and it can shapeshift into different things, and it can read your mind. So, if you're thinking you want to picture of something, like a picture of a beach background or something, it can read your mind and then it can give you that.*" P8 discussed the camera shapeshifting into different items that would be around you, such as scissors or forks, to be able to take pictures of people without their knowledge. Also, for *Shapeshifting*, P5 (11-year-old male) created a robot dog that could easily switch between being a real dog and a robot dog: *"So like, you can like, be like a normal dog and then you can switch it back."* P6 (nine-year-old female) agreed with P5 even stating *"At one point like it has like lungs, at another point and it has a chip in its brain."* While shapeshifting may not be feasible, we can take design recommendations from it such as devices having more of an adaptable form.

4.1.2 Device Physical Properties. In *Device Physical Properties*, we found that children designed tangible characteristics such as *Robots*, *Everyday Objects* and *Wearable Devices.* A prevalent theme was *Robots*, both in appearance and functionality. The children may have commonly included robots due to their prevalent nature in pop culture [7, 45]. The children showed an interest in designing devices with robotic attributes, such as wheels for legs, and robotic functionalities, including increased arm length for reaching and grabbing objects. Other themes included the incorporation of *Everyday Objects* and *Wearable Devices* into the designs. The children imagined smart devices that integrated into their daily lives, transforming ordinary objects into intelligent and interactive counterparts. P9, a 9-year-old male, shared his idea for smart glasses: *"So, I built a computer that it's not actually a computer, but it's like a computer and you wear glasses and then you can see monitors, [like] virtual reality."* In P9's idea, he explored the multifunctionality of these smart glasses, imagining scenarios such as playing chess with real-time guidance on winning strategies: *"Maybe I can play like chess with somebody, and the glasses would tell me how to win."* As mentioned before, P8 designed a smart Polaroid camera and she also thought of a smart refrigerator that would notify you if you're running low on food (Figure 3E): "*And then I made a smart fridge where if you're running low on any food, it will give a warning on the fridge and it'll like make a beeping sound. So, you know, and then on the fridge it'll be like warning, like how at school, once there's a fire drill.*" The incorporation of everyday objects into their concepts reflects a desire for integration of technology into daily life.

The children even considered *Size* in their designs, such as determining the size of an action figure or the size of a screen on a refrigerator. Children in previous work have demonstrated an understanding of how physical dimensions impact the practicality and usability of smart devices in different contexts [21, 58]. An intriguing aspect related to size was the discussion around extending the arm length of robots. The children envisioned robots with capabilities to reach and grab things that are not easily accessible. Reflecting a practical and problem-solving approach, the children perceive smart devices as tools capable of assisting them in various real-life scenarios. In examining the children's designs, we observed a focus on *Buttons and Click* interactions. The theme emphasizes

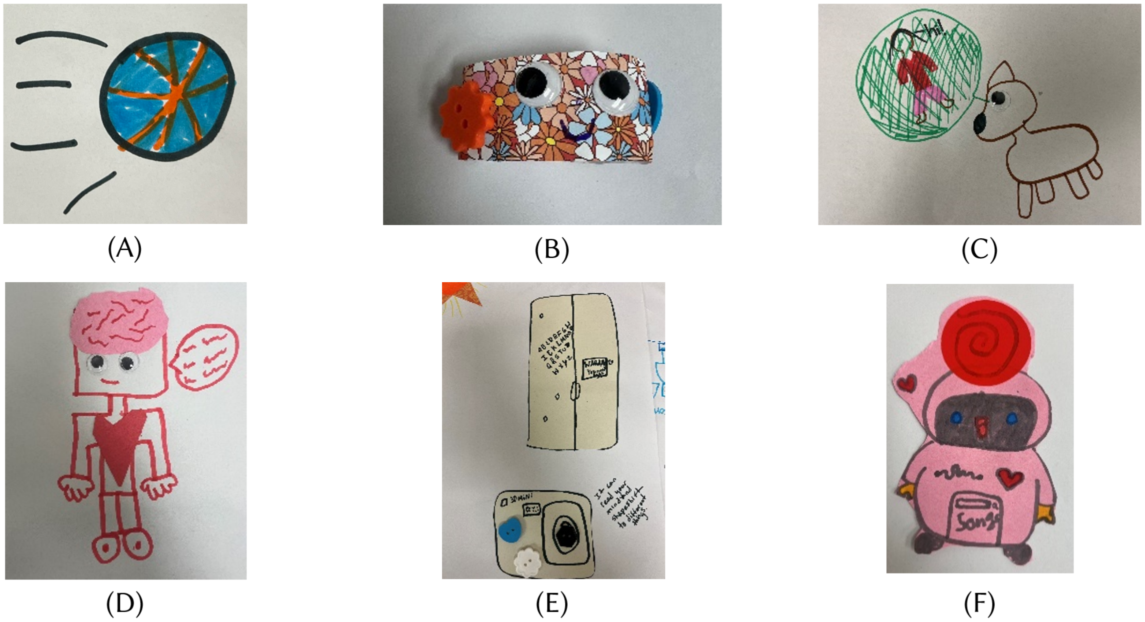


Figure 3: Examples of the children's designs (A) P1: ball that comes back to you. (B) P2: smart bracelet that talks to you. (C) P6: robot dog that is a phone and a pet and displays holograms. (D) P3: robot with emotions and a brain. (E) P8: smart refridgerator and shapeshifting polaroid camera. (F) P10: robot that can transform, play with you, and feel emotions.

their consideration of tangible input methods for smart devices. Whether integrated into wearable devices, everyday objects, or robots, *Buttons and Click* interactions were recurring features in their designs. P9 said, *"This button [on the robot] is to do my homework. This button is to do the chores. This button is to play games."* In P9's design, he assigned specific functions to buttons on his device.

We observed the children regularly associate complexity and difficulty in not only design, but also the inner working of the devices, such as programming, with a higher level of intelligence (*Difficult to Make*). We found that the children associated the perceived difficulty in creating a device with its level of intelligence. In one example, P9, was having a discussion on how the AR tablet is basic, because the other devices (i.e. Miko, AR Headset, and Alexa) are more complex. *"Like the virtual reality like that's like hard to make, same with the robot and Alexa. Cause that has more answers than the tablet games that you can put on any device and stuff like that."* P9's perspective showed the children's preference to associate advanced functionalities, such as virtual reality and robotics, with a higher level of intelligence. Another example includes when P4, P5, and P6 were discussing their thoughts on Alexa. They agreed that Alexa was smart due to having a lot of information, and P4 stated *". . . it takes a lot of like, like coding stuff. It's just, and it can like answer like questions, just the bunch of stuff, so pretty smart."* The children understood the intelligence of Alexa, emphasizing the amount of coding involved in Alexa's creation.

4.1.3 Context of Use. During the design sessions, the children thought of using the smart devices for both *For Help* and *For Fun*. *For Help*, had a wide range of areas such as homework/work, chores, answering questions and even help sleeping and reaching objects. While it's common for children to want to seek assistance from technology with tasks like homework and chores [9, 42, 50, 52], some participants showcased unique and interesting perspectives. The children's considerations extended beyond typical tasks, for instance, P10, a 10-year-old female, wanted her robot to transform into a lamp that changes color to help her sleep (Figure 3F). As mentioned previously, P8 created a smart refrigerator that notifies users when food is running low, demonstrating an understanding of using everyday objects that can be helpful to users. P4, an 11-year-old male, created a robot math monkey that sits on your shoulder like a parrot and helps with math homework: "*I'll talk about the math monkey. Alright, so, it's a monkey that can like move around, do like things, talk to you, not like talk, like like have conversations, but like if you're like having trouble with like math homework you can ask it for that and you can just like play with it and stuff.*" P7 created her action figure to help parents get their children to listen to them: *"So I'm drawing an action figure that can talk to kids so it can, so since kids don't listen to their parents, they could prob, they're probably gonna listen to they're, uh, idol, which could be like an action figure or maybe like a movie star."* P6 (9-year-old female) designed a smart dog, with the ability to motivate the user to exercise and go on walks outside. These requests emphasize the children's ability to view technology not only for routine tasks but also for personally helping the user.

For Fun, the children envisioned smart devices that not only served practical purposes but also included elements of joy and amusement. Some children expressed their desire for devices that brought a playful interaction with their device. Some examples involve P9 discussing what he could do with his device: "*Hmm. I* *don't know. I'm thinking, uh, it [the robot] have like a laser tag fight*" and P10 stating what she wanted to do with her robot: *"Maybe we, we could like we could do crafts together."* P7 explained her action figure functionality by saying *"Oh, probably like, probably like more like communicating maybe like the Alexa probably like give, give answers and probably will have like a screen on stomach or something so they can play games too."* P1 even created a robot spider, in which the only functionality was to follow the user around for fun. These insights reflect the children's inclination to infuse games into the functionalities of their smart devices, showing a blend of practicality and entertainment.

4.1.4 Human Characteristics.

In the children's designs, they commonly included human-like attributes, such as *Friendship and Companionship, Emotions* and *Human Physical Characteristics.* The three themes shed light on the children's desire to combine smart devices with qualities resembling human attributes. *Friendship and Companionship* emerged as a prevalent theme, illustrating the children's ideas of smart devices as more than mere tools. The children envisioned robots and devices not only capable of playing with them and performing tasks but also providing companionship during moments of solitude. For instance, with P10's robot that could change colors and express emotions: *"My robot can play with you and help you. And be your friend when no one else is there. And when you want to listen to a song with your robot and dance with your robot, you can search up a song and then you can press the little heart to make the robot say, I love you."* P2 (7-year-old girl) discussed that she wanted her device, a smart bracelet, to simply talk to her as a friend (Figure 3B).

Beyond recognizing and responding to human emotions, the children envisioned devices that could feel *Emotions.* P3, an 11-year-old male shared his idea (Figure 3D): *"I made a robot that can feel feelings, change its voice and stuff, and like think what you're thinking basically."* Touching back on P10's robot, she designed a heart on the device, and when you touch the heart, the robot responds with a heartfelt expression, saying "*I love you*". These ideas not only demonstrate the children's desire for emotionally intelligent devices, but also devices that include sentimental functionalities.

The children also incorporated Human Physical Characteristics into their smart device designs (e.g., heart, brain, facial expressions). For example, even though P3 and P6 were in different design sessions, both designed robots with a brain. P3 highlighted the importance of a brain in defining intelligence (Figure 3D), and P6 said "Put his brain on the outside. You have to see how smart he is. Yeah, then you can trust him." P6 correlated trust with the visibility of the device's "brain." The discussions on the physical appearance of the devices revealed diverse ideas, such as the inclusion of customizable voices and even x-ray vision. The children's designs also included devices with legs, which would walk akin to humans. While earlier it was discussed that the children demonstrated a keen interest in designing devices with robotic attributes, such as wheels for legs, this example revealed a broader range of ideas. The children's designs showed a variety of preferences, ranging from robots with legs to those with wheels, emphasizing the various ways in which they imagined smart devices. This variety in design preferences suggests that the children appreciate having both realistic human-like characteristics and more robotic features in their envisioned smart devices.

4.1.5 Immersive Capabilities.

When examining *Immersive Capabilities*, the themes of *Virtual Elements*, *Customization and Individual Experience,* and *Visual Aesthetic/Visual Elements* were shown throughout the design sessions. The children expressed a strong desire for devices that would combine virtual elements with the real world, providing an immersive and enchanting experience. One example was P6's design of a robot dog that served as both a phone and a pet, which would display holograms and alleviate the responsibilities associated with a real pet (Figure 3C): "*It's basically like a phone, yeah. So, it's like, um, It, it's a dog. It's like if you want a pet where you can like, like I want a dog, but my mom's like, no, it has too many responsibilities. So basically, um, like it, it won't poop or pee because Yeah. Yeah. It can take care of itself.*" P6's idea not only reflects a desire for immersive experiences but also demonstrates a practical consideration, as she acknowledged the challenges of taking care of a real pet. Also, as previously mentioned, P9 designed smart glasses that would show different virtual screens. The inclusion of holographic capabilities in the robot dog and virtual screens in smart glasses show the children's creativity in designing devices that integrate the virtual and physical world.

The second prominent theme was *Customization and Individual Experience*, emphasizing the importance of personalization and individualized experiences. The children expressed a keen interest in shaping their devices according to their preferences, fostering a sense of ownership and connection. The children envisioned the ability to customize robots with their own original designs, patterns, and even the option to change the robot's height or make it talk like a chosen character. Also, the children's desire for personalization included tailored interactions with their devices. For example, P9 designed a cape that would provide the specific user with a superpower. When questioned about whether the superpower would be the same for everyone, P9 clarified that the experience was tailored to the individual. *Visual Aesthetics* emerged as the third theme, highlighting the children's attention to the appearance of smart devices. For instance, P1 discussed a robot that had a visual screen that would display different aesthetic patterns. These findings suggest that the success of smart devices for children lies not only in their functional capabilities but also in their ability to deliver captivating and personalized experiences.

4.2 Interactions and Intelligence of Smart Devices

In our study, the children interacted with four commercial devices: a social robot (i.e., Miko), Magic Leap 2 AR Headset, Amazon Echo (i.e., Alexa), and a Samsung Galaxy A8 tablet with AR applications (i.e., AR tablet). The children also participated in a *Line Judging* activity, in which they rated each device. To help provide context for our observations, we did a quick analysis of the children's ratings. We broke down each image of the line judging ratings into four equal sections and provided a number to each section (1-4, not smart to intelligent) (Figure 4). If a child was standing between two sections, we selected the lower rating. Our goal was to give more context to our findings, not to complete a quantitative analysis on

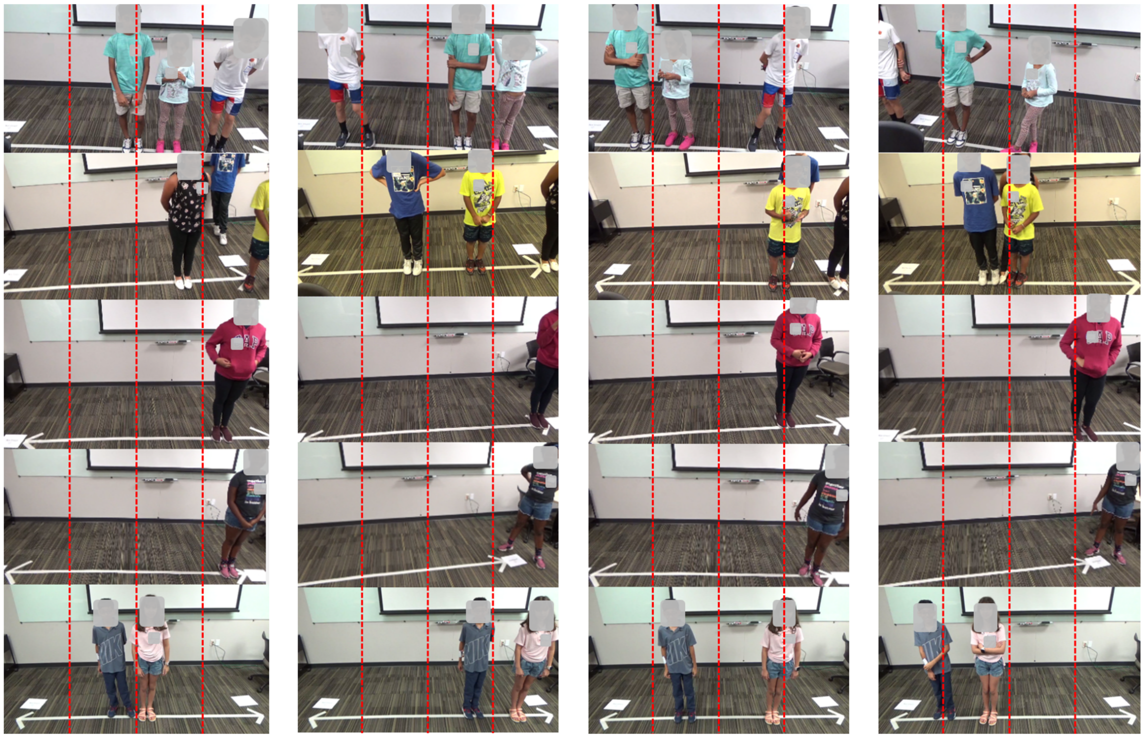


Figure 4: The children's ratings of each device during the Line Judge Activity. The red lines are added on top of the images to show the breakdown of the four sections (1-4, not smart to intelligent): (A) Miko (B) AR Headset (C) Alexa (D) AR Tablet.

the children's ratings. The children rated the Miko as the most intelligent (M = 3.3, SD = 0.82), followed by the AR headset (M = 3.2, SD = 1.03), Alexa (M = 2.9, SD = 0.99), and AR tablet (M = 2.5, SD = 1.08). We grouped the children's utterances during the interactions and line judge activity ratings into three groups: *Positive Interactions*, *Negative Interactions*, and *Interaction Content*.

4.2.1 Positive Interactions. In examining children's interactions with smart devices, we observed positive interactions with the devices. The AR Headset emerged as a favorite, with the children expressing their enthusiasm for the device. P1 shared the uniqueness of the headset, emphasizing how the AR Headset could create its own virtual world, stating *"I mean, it was kind of like unique, like you go, like you're in the real world and, but you could still like draw it and no one else could see it."* P9 and P10 both reflected on the AR Headset, specifying their excitement of drawing and the immersive experience it offered. P10 even compared the AR Headset to real life activities: *"Beautiful, it looks like, it feels like I'm spray painting."* P8 appreciated the feeling of drawing in the air saying: *"But for that, it feels like it's real and you can draw on the air and stuff."* P5 and P6 expressed their enjoyment of the AR headset, with P6 specifically mentioning the joy of drawing mustaches on her brother. P7 expressed her thoughts on the AR headset by saying *"I thought it was really cool how you can like draw through, like with the brush instead of like painting on real paper because that's kind of boring. No, but like, uh, with the AR headset, you can draw like in real, uh, environments and you can, um, and you can also like draw, it's like, it's like your drawings are like floating in the air."* The children envisioned their drawings coming to life and liked the feeling of the combination of the virtual and physical world.

In addition, to the children's positive interactions with AR headsets, they also had positive experiences with the other smart devices. P1 appreciated the multifunctionality of Miko, mentioning the ability to play games and move around: *"Well, it could move first and like it can move around and it knows where it's going. And it also has like a camera to also see what it's doing."* The children favored smart devices that engaged in different activities such as games and movement, with P5 also mentioning Miko's ability to move and play games *"like you can move and like, you can also, it's like Alexa. . .plus it's a robot, plus you can play games on it. So, like, it's all combined like a really intelligent robot."* P4 added to the positivity stating: *"Like it's [Miko], it's hard to process everything and it can and like play games and she was smart."* P8 also provided positive feedback on Alexa stating it can answer various questions and play anything: "*Because it knows, it always knows the weather and the forecast for every single day, and you can just ask it random questions and it knows. Like, you can ask the questions that nobody, that nobody knows."*

4.2.2 Negative Interactions. As we explore the children's interactions, it is crucial to recognize instances in which the experience fell short of their expectations. The children frequently commented about the smart devices not being able to recognize and respond accurately to their interactions. For instance, P1 and P2 critiqued Alexa for struggling to comprehend their questions. P1 noted, *"Sometimes when you ask questions, it doesn't really respond that well, and it's like, 'I don't understand,' and it doesn't really talk like a human that much"* and P2 added, *" It can't hear you that much."* P2 also thought the Miko struggled with recognition, stating *"...sometimes it doesn't, um, like hear what you say"*. The children also critiqued the devices for struggling to recognize the environment. For instance, P3 was annoyed with the AR tablet: *"Because like, so like whenever you click on the game, it's like, like show a flat area around you, but the, whenever you're like showing the flat area, it takes like 2 billion years to find it. So yeah, [it] couldn't really sense what was around you too much and it was kind of confusing."* P3 also commented on Alexa not being able to recognize people in the area: "*um, in for Alexa um, a bad thing about it is like, so like when you like, Hey Alexa, and then other people start talking it starts like sensing the other people's voice.*" Improvements on environmental recognition would enhance the children's experience with smart devices. The AR tablet also faced criticisms for its limitations in human-like interaction. P4 remarked, *"Well, cause the camera just tracks the AI onto the screen. It can't really like talk to you or like do any of that. It's just an AI type thing."* P5 expressed that the tablet was not intelligent because it was not novel, stating, *"And I think that's a, like they are not so intelligent because like lots of um, things are, are like that."* P9 also mentioned how *"It [tablet] was, it was very basic and it was just like a tablet and all the other ones were more like complex."*

The children shared their perspectives on smart devices' virtual elements, shedding light on their preferences for more immersive experiences. P10 highlighted a limitation in Miko's capabilities when asked why she thought Miko was not as smart as the AR headset stating, *"Well, because it couldn't draw things around the camera [researchers' video camera]. Couldn't draw mustaches on everyone."* This observation reflects the participants' desire for smart devices to provide more interactive and creative virtual elements, contributing to a more engaging experience. P9 echoed this sentiment, emphasizing that Miko lacked the virtual reality aspect, stating, *"Because yeah, it wasn't virtual reality and you had to actually click on stuff and stuff like that. Yeah. Yeah. I didn't like it too much..."* In addition to wanting more interactive virtual elements, the children wanted the elements to be more realistic and recognize the environment. P1 critiqued the AR tablet when the virtual elements failed to detect real-world environment: *"It doesn't really make sense how it just phases through the chair. It couldn't sense the chair. Yeah. And it like doesn't look that real on the camera."*

The children highlighted instances in which smart devices failed to provide clear guidance, impacting the overall user experience. For instance, P7 critiqued Miko for its lack of guidance when using the Freeze Dance app stating *"I'm so angry. I did not know how to do that one"*. The children's lower rating of the AR tablet illustrates a preference for devices with more complex functionalities. For example, P4's statement on AI tracking on the screen and P5 adding on saying "*I think like we got that kind of thing. Cause it's like a normal game [...] I think that's a, like they are not so intelligent because like lots of um, things are, are like that.*" Additionally, several children expressed difficulties with the fit of the AR headset, such as the headset being too big. For instance, when asked if there was anything they disliked about the AR Headset, P10 responded *"It didn't fit me."* These instances of negative interactions offer valuable insights into the areas that may require improvement in smart devices' design and functionality to better align with children's expectations and enhance overall user satisfaction.

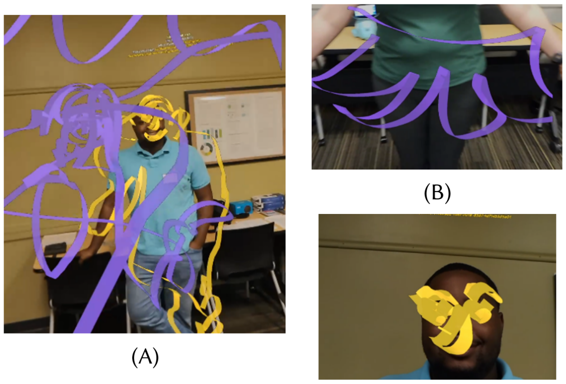
4.2.3 Interaction Content. During the children's interactions, they engaged in conversations with smart devices, seeking responses that simulated human-like conversation. For instance, P8 initiated a conversation with Miko, asking, *"Hello Miko. Are you smart?"* Miko responded *"What if I said I can answer 8,085 types of questions?"* P8, in turn, responded to Miko stating "*That would be smart.*" Similarly, questions posed to Alexa, such as *"Hey Alexa, when were you made?"* (P10) reflect an attempt to engage in personal conversational interactions with the device. P8's inquiry to Miko about its intelligence level and P10's question to Alexa about its creation date exemplify children's curiosity and desire to understand more about the devices they interact with. Children sought information from smart devices by posing questions related to various topics. The informational aspect of interactions is evident in queries like, *"Hey. Hey Miko. How old is LeBron James?"* (P5). Our findings are similar to prior work, which have found that children commonly ask voice assistants informational questions, jokes, and personal questions about the device [22, 24, 31, 32].

The children actively engaged in gaming experiences with the smart devices, adding an element of entertainment to their interactions. All the children took part in playing Charades and Freeze Dance with Miko and P3 appreciated Alexa's game-like features, which emphasizes the importance of games in enhancing the overall user experience. Humor played a role in the children's interactions, with the children providing feedback on the quality of jokes delivered by smart devices. P9's criticism of Alexa's jokes, stating, "*Because the jokes are bad*" indicates a desire for more entertaining and engaging content that relates to children.

The children expressed interest in virtual elements combining with the real world, as observed in their interactions with devices like the AR headset. P7's description of drawing in real environments and having the drawings appear as if they were floating in the air exemplifies the desire for a seamless blend between virtual and physical spaces. When using the AR tablet, the children showed a tendency to talk with the virtual elements, including animals. P10 selected a dog in the *ARLOOPA* application and began talking to the animal: "*All right. My sweet, sweet puppy come with your mother. You aren't listening to me; no, I will abandon you muwahaha.*" With the AR headset, the children drew objects on the researchers, such as mustaches and tutus (Figure 5). Collaborative aspects were shown in P8's attempt to teach science and math to the researchers with drawing in the AR headset: "*You can sit. I'm going to act like I'm a teacher, so sit. Sit in the chairs... You're going to be learning science, so, so like, tell me what science is. Oh, raise your hand.*" This collaborative element adds a social dimension to smart device usage, enhancing the overall engagement.

5 DISCUSSION

We focus our discussion on (1) summarizing our findings in relation to prior work on children's perceptions of smart technology, (2)



(A) (B) (C)

Figure 5: The children virtually drew on the researchers using the AR headset by: (A) tracing their bodies, (B) drawing tutus, and (C) drawing faces.

discussing current limitations with existing smart devices, and (3) suggesting new design recommendations on designing future smart devices that match children's expectations.

5.1 Summary of Our Findings vs. Prior Work

In comparing our findings to existing research, we observe several similarities, such as the emphasis on the device being able to recognize the user, environment, and itself [50, 52]. For instance, Woodward et al. [52] examined how children conceptualize intelligent user interfaces and found that the children expected a high level of recognition, as well as meta-intelligence (i.e., the device would understand itself). Additionally, our finding on integrating virtual elements within the real world aligns with observations from previous work [36, 40]. For instance, Sim et al. [44] found that children want interactive AR experiences, such as fighting a Roman soldier in a museum exhibit. The children's desire for immersive interactions emphasizes the importance of incorporating features that allow users to actively participate in shaping their virtual surroundings. In our findings, the children incorporated imaginative features like shapeshifting, emotions, and human-like attributes into their designs. Prior research has shown that children want smart devices to have the ability to recognize the users' emotions as well as have their own emotion [17, 52]. We also saw that the children want smart devices to move and allow user mobility, which is similar to prior work [17, 50]. Woodward et al. [50] investigated how children conceptualize AR headsets and recommended that AR headsets for children allow for extensive mobility and recognize whole-body input.

In our study, we found that the children associated the perceived difficulty in creating a device with the device's level of intelligence. For example, the children considered augmented reality and robotics as more complex to make and, therefore, of higher intelligence. Also, the children favored devices that demonstrated versatility and multifunctionality, and wanted devices to include human physical characteristics. Yip et al. [61] found that children view robots that are too humanoid as "creepy". In our findings, children expressed a preference for devices with subtle human-like features, such as a robot with a heart or brain. Our findings on complexity, immersive experiences, and practical functionality add depth to the understanding of how children perceive and interact with smart technology. These themes are expanded on below, in our section on Design Recommendations.

5.2 Negative Interactions with Smart Devices

As mentioned above, the children commented about negative experiences with the devices, such as issues in user recognition (e.g., not recognizing their speech). This is similar to prior work [37] which has shown children's recognition rates are lower than adults for a range of devices, such as voice assistants [24, 31, 32] and smartphones [3, 51, 54, 55]. Additionally, our study revealed that the children expressed concerns about unclear instructions with current smart devices, such as when P7 critiqued Miko for its lack of guidance when using the Freeze Dance app, as mentioned above: *"I'm so angry."* The findings show the importance of addressing recognition challenges and providing clear instructions in the design and development of smart devices intended for use by children. By acknowledging and mitigating these issues, designers can enhance the overall user experience and usability of smart technologies for younger users. P4 and P5 drew attention to the limitations in human-like interaction, particularly in the context of the AR tablet. For instance, P4 critiqued the tablet by highlighting its lack of human-like conversations: *"It can't really like talk to you or like do any of that. It's just an AI type thing."* P4 viewed the device as more of just an artificial intelligence (AI) device rather than a human-like interactive entity, which he considered more intelligent. Designers can explore incorporating more advanced conversational interfaces that incorporate natural human interaction, to create a more engaging user experience.

The children wanted more interactive virtual experiences, as exemplified by P10's critique of Miko not being able to draw elements in the environment. In addition, the inability of the AR tablet to detect real-world elements, such as phasing through a chair, led to the children's confusion and dissatisfaction. This emphasizes the need for improved realism in virtual elements to create a more authentic and believable augmented reality. By addressing these key areas – recognition of the user and environment, human-like interactions, realistic virtual elements, and immersive experiences, – designers can refine future smart device designs to better align with children's expectations, ultimately enhancing the overall user satisfaction and engagement.

5.3 Design Recommendations

Based on our findings, we suggest recommendations for designing smart technology experiences for children. In each subsection we connect the recommendation to the themes we found. Existing and future designers of smart devices for children can utilize our findings to examine if their designs match children's expectations.

5.3.1 Highlighting Complexity of Device. Our findings revealed that children associated the perceived complexity of smart devices with intelligence (*Difficult to Make*). For example, P9 rated the AR tablet low because it was not hard to make: "*Like the virtual reality like that's like hard to make, same with the robot and Alexa.*" Rubegni et al. [30] found that children have a lack of trust in robot cognition due to concerns about the lack of transparency in programming and operation. Also, Yip et al. [61] found that children want more transparency from designers in helping them understand how technology works and whether it is trustworthy. Therefore, to increase children's perception of intelligence and trustworthiness, we recommend that designers should prioritize devices being transparent on what is happening in the background of the device. For instance, smart devices should inform children when they are trying to recognize the user and environment. In addition, introducing features perceived as complex may enhance children's perception of devices' intelligence and contribute to a more engaging experience.

5.3.2 Human Physical Characteristics. Our findings show to incorporate human physical characteristics, such as a heart or brain, in addition to more robotic or animated features; making sure to include emotions (*Human Physical Characteristics, Robots, Emotions*). In research by Tung [47], applying human-like traits in a robot's appearance can enhance its social acceptance and visual appeal. This aligns with our findings, which emphasize the importance of incorporating human physical characteristics into smart devices for children. For instance, P3 and P6 wanted to include a brain in their robots to illustrate intelligence, as well as P6 wanting it on the outside because: "You have to see how smart he is. Yeah, then you can trust him." However, Yip et al. [61] found that children perceive robots that were too humanoid (e.g., robotic human doll that laughs and blinks eyes) as "creepy". We recommend incorporating human physical characteristics into devices but keeping a balance with animated or robotic features.

5.3.3 Collaborative Immersive Experiences. In our study, we frequently observed the children wanting to have collaborative experiences with the devices, especially the AR headset (*Immersive Capabilities*, *Interaction Content*). For instance, P8 wanted to teach the researchers science and math by writing virtual content in the AR headset. In contrast, we also found that children still wanted individual experiences. For instance, P1 enjoyed individually interacting with the AR headset, even comparing it to *"its own kind of like world"* and that *"no one else could see it"*. Currently, interacting with AR headsets is more of an individual experience; therefore, we recommend designers to also emphasize collaborative experiences. Collaboration benefits children's cognitive and social development [43]. Also, prior research [38] shows, that collaborative augmented reality experiences can support children's conceptual understanding of information. Designers can enhance collaborative potential by considering external screens or collaborative AR glasses so people can view what the user of the headset is doing. To continue to support individual experiences, designers could include a toggle to let users decide when and what they want to share.

5.3.4 Having Multi-Purpose Functionality. We found that children value smart devices that serve multiple purposes (*For Help*, *For Fun*). For instance, P9 created a robot that would include different buttons: *"This button was for chores. This button was go to games."* The children wanted smart devices that could effortlessly switch between practical applications, like educational assistance (*For Help*), and entertaining activities (*For Fun*). Designers should focus on creating devices with multi-purpose functionality to meet the children's needs and preferences. Incorporating features that allow seamless transitions between different modes of use ensures that the device remains engaging and relevant to children across various contexts.

6 LIMITATIONS AND FUTURE WORK

There are limitations to the scope of our work. For instance, our study involved 10 children. Although this number might seem small, it is consistent with prior PD sessions with children (e.g., [4, 24, 50, 61]). Additionally, despite diversity in gender, ethnicity, and age among the children, it is important to note that they were all from the same local area; therefore, their economic, social, and cultural backgrounds might share similarities. Future work should recruit children from other geographically distributed areas. In addition, the children only interacted with four commercial smart devices. To broaden the scope, future work could examine children's perceptions for different smart devices (e.g., smartwatch).

7 CONCLUSION

Although children continue to use smart devices, there is limited knowledge on what children define as "smart" for technology. Understanding what children expect as "smart" would ensure more effective positive experiences with smart devices. To examine children's expectations, we conducted five participatory design sessions with 10 children focused on designing smart technology. The children also interacted with four commercial smart devices, including a social robot (i.e., Miko), Magic Leap 2 AR Headset, Amazon Echo (i.e., Alexa), and a Samsung Galaxy A8 tablet with AR applications, and judged them based on intelligence. We found that children expect smart technologies to have advanced intelligence, human-like characteristics (e.g., emotions, brain), immersive experiences, and serve multiple purposes. Also, children thought smart devices should be difficult and complex to make. Our study showed instances of negative interactions with current smart devices, like physical limitations and issues with device responsiveness. Based on our findings, we present new recommendations for designing "smart" devices for children that align their perceptions and understanding. Our findings can inform the design and development of future smart technology devices, ensuring they are engaging and aligned with children's needs and preferences.

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SELECTION AND PARTICIPATION OF CHILDREN

Children (ages 7 to 12) were recruited from the community, including a local elementary school, library, and neighborhood community center. Flyers were posted at these locations with appropriate permission. The study information and flyer were also sent out in an email through institutional listservs, one that included staff and faculty and the other that included local elementary principals. Parents who were interested reached out to the researchers by email to schedule a time to bring their child to our institution. The researcher conducting the study went over the parental informed consent with the parents, and if they consented, the parents left the room and then the child was asked to assent to the research. During the assent process, the researcher explained the length of the study, the tasks, the devices, that they were being audio and video recorded, and informed the child they could take as many breaks as they wanted, and they could stop at any time. If all the children verbally assented the researcher started the study. During the study, the children had a scheduled break after the design activity. All data was anonymized and stored in secure locations only accessible to the researchers.

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