Interactive Technologies Designed for Children with Autism: Reports of Use and Desires from Parents, Teachers, and Therapists

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Autism spectrum disorder (ASD) affects many people; the Center for Disease Control and Prevention estimates that 1 in 59 children are currently identified with ASD in the United States. Although it is difficult to generalize about people with ASD due to their heterogeneity, many share an affinity for technologies; as such, numerous academic endeavors and commercial products have focused on the creation of interactive technologies for ASD. In this article, we present findings from 19 interviews and 230 surveys with parents, teachers, and therapists who had children with ASD in their care and had considered or used interactive technologies with those children. We aimed to understand how interactive technologies were used, perceived, desired, and discovered. Findings of use and perception included the following: participants had tried a wide range of commercially available technologies but had very few reported products in common, products were limited to commercial mobile-based apps, and apps were typically perceived positively. In regard to desires, participants hoped for future technologies on diverse platforms (e.g., robots, virtual reality) with more consideration given to personalization, customization, and incorporation of audio and video. Findings about discovery included the following: participants chose technologies in an information-poor environment, and although there are many academic projects aimed at participants' desires, no participants reported any experience working with researchers. Implications of this study include the need for a recommendation and information sharing system to help people choose and discover appropriate and effective interactive technologies that are a good fit for their child. This work also pointed to a need for such a system to include findings from lab (experimental and usability) studies of commercially available interactive technologies to provide measures of efficacy and usability. Our envisioned system could also potentially help academic researchers with outreach to wider audiences.

CCS Concepts: • **Human-centered computing** → *Accessibility*; *Accessibility technologies*;

Additional Key Words and Phrases: Autism, interactive technologies, children

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1 INTRODUCTION AND BACKGROUND

Autism spectrum disorder (ASD) affects many people. The Centers for Disease Control and Prevention (CDC) estimates that about 1 in 59 children are identified with ASD in the United States [6]; this represents about a 49% increase from the 1 in 88 estimates in 2012. There is no biomarker for ASD; instead, it is diagnosed by analyzing a child's behavior(s) and conditions under which the behavior(s) need to occur.

The DSM-V identified five diagnostic criteria and three levels of severity [2]. The first two diagnostic criteria describe behavior: (1) evidence of deficits in language (e.g., non-verbal) and social interaction (e.g., inability to make friends) and (2) display of a restricted/repetitive pattern of behavior and/or interests (e.g., demonstrated by echolalia, hand flapping, and/or obsession with topics/toys). The last three criteria describe conditions (when, how, and why) under which the behaviors need to occur for an ASD diagnosis: (3) when—that the non-typical behaviors described are displayed in early development, (4) how—that the behaviors impair the child's ability to function typically, and (5) why—that the behaviors are not attributed to another cause (although comorbidities with other intellectual impairments do occur).

On the most impacted end of the ASD spectrum are children categorized as Level 3 (requiring very substantial support). Children categorized as Level 3 display severe deficits in verbal skills, ranging from no speech to very limited vocabularies, and have minimal abilities to respond to others in social situations [2]. Additionally, children categorized as Level 3 may display extreme discomfort with change and/or transitions (i.e., switching to new activities), which has resulted in disruptive behaviors. On the other end of the spectrum, children are categorized as Level 1 (requiring support). Children categorized as Level 1 demonstrate normal to high intellectual abilities (e.g., have verbal skills) but may have decreased interest in social interaction and/or display odd behavior when interacting with others. Although children diagnosed at Level 1 may have difficulties coping with transitions, the level of distress is not as severe as those categorized as Level 2 or 3 [2]. It is also common for people with ASD at all levels to have sensory sensitivity ranging from undersensitivity (e.g., may enjoy noisy rooms, no sense of smell, enjoy pressure) to oversensitivity (e.g., avoidance of bright lights and not liking to be touched) [38]. In other words, as a spectrum disorder, there is considerable heterogeneity in how the population exhibits and experiences autism.

Although heterogeneity is an apt descriptor of the ASD population, multiple researchers have noted that many people with ASD have an affinity for technologies [44]; this has led to numerous academic endeavors and commercial products focused on the creation of interactive technologies aimed at the ASD audience. (We have operationally defined *interactive technology* as a digital-based experience that facilitates a flow of information between a user and a technology where users initiate the information exchange; this includes toys, digital games, robots, apps, software, and Web-based experiences.) In further support, technology-based instructions and interventions (TAII) are highlighted by the Autism Evidence-Based Practice Review Group from the University of North Carolina at Chapel Hill as a category of evidence-based practices for children and young adults with ASD [85]. In this article, we present findings from 19 interviews and 230 surveys with parents, teachers, and therapists who had children with ASD in their care and had considered or used interactive technologies with those children.

Specifically, we aimed to better understand three aspects of current offerings of interactive technologies: use (i.e., what technologies and platforms teachers, parents and therapists were using with the children in their care?), objectives (i.e., what goals did the technologies purport to address?), and satisfaction and success (i.e., how well did the technologies address their goals?) We also explored how people discovered the interactive technologies they had used. And for those who had not used any interactive technologies, we asked about their reasons for not using them. Last, we focused on desires. Specifically, we asked participants what they wanted in technology design for their children with ASD. This last query was a follow-up and an extension of earlier work that we published in 2008 [50].

In our earlier work [50], we conducted online surveys with 114 parents, teachers, and therapists who had children with ASD in their care (79% parents). We found that relatively few (25%) had ever used any interactive technologies, and that only 7% used interactive technologies specifically designed for ASD. When asked an open-ended question about what they desired in technology design, respondents focused on improving three skill areas that represented common challenges for children with ASD (i.e., academic, social/communication, and organization). In the 11 years since that work was published, the rate of reported ASD diagnosis has grown exponentially. Additionally, we have witnessed a proliferation of new platforms (e.g., tablets), commercial products, and related academic research projects; as such, we felt that this research updating our understandings was much needed. In the next section, we provide an overview of technologies and research projects that exemplifies an increased focus on ASD-aimed technologies.

1.1 Background: Interactive Technologies Aimed at/for ASD

In this review, we did not attempt to include every related project/product; other authors have published more comprehensive reviews (e.g., [30, 37, 53]). Instead, we provide a high-level overview that emphasizes how ASD-focused technologies and research about them has proliferated over the past decade. For the academic work, we limited this review (with a few seminal exceptions) to work published since our last work (2008) that are/were either publicly available or at the level of a functional prototype. We organized this section into in two categories: (1) interactive technologies designed specifically for people with ASD (1.1.1) and (2) academic research on mainstream interactive technologies for use by people with ASD (1.1.2).

1.1.1 Technologies Designed Specifically for People with ASD. For organization, we leveraged (and slightly modified) the classification scheme outlined by Kientz et al. [37] in their 2013 review of ASD-related interactive technologies. They organized their review by platform[1]: personal computers (PCs) and the Web, video, mobile devices, shared active surfaces, virtual reality (VR), and robotics.

PC/Web Platform. There are many commercial PC/Web products and multiple research projects using exploratory functional prototypes created by academics in this category. Commercial examples include TeachTown, Discrete Trial Trainer (DTT), and the Zac Browser:

(a) Teach Town [69] is a publicly available commercial software product aimed at teachers and their students ages 2 through 7 years; the software provides multiple lessons aimed at a range of academic, social, and communication skills. In a 2010 study in 47 classrooms in the Los Angeles School District, researchers compared TeachTown to a control condition; findings indicated that students in the TeachTown group improved their cognitive and language skills significantly more than those in a control group [84].
(b) DTT [19], created by Power Tools for Autism, is aimed at children ages 2 through 9 years. The software provides adjustable learning modules focused on multiple skills that include counting, word analysis, and sequencing. DTT utilizes the evidence-based applied behavior analysis (ABA) approach.

[1] Although not all products/projects fit neatly into one technology platform, we used this taxonomy to simplify our discussion.

(c) The Zac Browser [86] was designed specifically for children with ASD to address overstimulation (visual and auditory) while using the Internet. The browser helps solve overstimulation by organizing appropriate child-focused Internet content into categories that are accessed through icons. Although were not able to find any academic studies that assessed the Zac Browser, testimonials from parents were positive. (There are also other similar browsers designed for children—but not specifically for children with ASD—that might also be appropriate, such as the KIDO'Z browser, which requires a paid subscription [39].)

Several academics have created and evaluated exploratory functional prototypes on PC/Web platforms; many use game-like approaches. Examples in this category have focused on goals that include improving academic outcomes (e.g., [52, 82]), help for language-communication skills (e.g., [20, 29, 47]), life/vocational-related skills (e.g., [16, 32]), and social and emotional interaction (e.g., [1, 41, 73]). We highlight a few examples in the following list:

(a) *Improving academic outcomes*: Weilun et al. [82] developed PC-based gamified quizzes presented by digital avatars aimed at several academic skills including basic math, telling time, and color recognition. Their evaluation of the quizzes was from a usability perspective; six of the eight children with ASD successfully interacted with the quiz/games.
(b) *Help for language-communication skills*: Mendonça et al. [47] generalized a platform designed for aphasia treatment in adults, named VITHEA (Virtual Therapist for Aphasia Treatment), for children with ASD. Interacting with VITHEA requires users to orally reply to a set of stimuli (e.g., naming an object), and their responses are assessed through voice recognition. Their modified platform allowed caregivers to customize stimuli based on a child's needs and abilities.
(c) *Life/vocational-related skills*: Hassan et al. [32] developed and evaluated a game aimed at helping teens with autism learn about money using storytelling. In their evaluation with five children with ASD, they found that their game helped in explaining the concept of money; however, they did not thoroughly investigate how the knowledge generalized to purchasing items outside of the game.
(d) *Social and emotional interaction*: Several interactive game-like prototypes have been created to help with understanding emotions that people exhibit through facial expressions. An early seminal example is the Mind Reading software by Baron-Cohen [10]; the software was evaluated through several studies that indicated an improved emotional score after interacting with the program [40]. In a more recent example, Abirached et al. [1] designed and evaluated an emotional understanding game with seven participants with ASD who reacted positively to the game.

Video. Many people with autism are thought to be visual-based learners [62]; as such, the use of video-based modeling has been researched and established as effective for this audience [63]. In a commercial example, Power Tools for Autism offers a video creating system that leverages Social Stories [66]. In another commercial example, the now-defunct publicly available Web site "Look at Me Now" [43] provided an extensive library of videos that captured novel experiences in which a child may feel anxious (e.g., going to the doctor) and modeled personal hygiene (e.g., brushing teeth). It required adult users to upload and edit a picture of the targeted-child's face, which was then superimposed onto the main character in the videos.

Chen et al. [21] analyzed a similar video approach, in which they had superimposed two teen-age participants' faces on a main character in a video depicting a visit to the dentist. Their participants felt the video would reduce anxiety and stress associated with going to the dentist. Weiss et al.

[83], taking a participatory design approach, co-created customized videos with a single person with ASD. The videos aimed to help the participant work through problematic situations. At the time of this writing, they had evaluated their system with 16 therapists who were enthusiastic about the authors' approach.

Mobile Devices. This category includes technologies designed for handheld devices (e.g., smartphones, tablets) and augmentative and alternative communication (ACC) devices. There is a large number of commercial apps in both Google and the iTunes store; at the time of this review, a search for autism in the iOS app store resulted in more than 80 apps for the iPad and iPhone.[2] Apps specifically designed for children with autism include educational games (e.g., [4, 5]) Social Stories [35, 64], help with scheduling (e.g., [77 ,78]), and tools for tracking events and progress (e.g., [8, 55]). Unlike other interactive technologies in this review, most apps have ratings and reviews; however, it can be fairly arduous to search through reviews to discover reported efficacy for a particular child's profile.

There are also many commercially available mobile ACC devices. Examples include Tobii Dynavox [71], which is a touch-based and/or eye-gaze controlled communication system, and GoTalk products [29], which are a series of devices that display images (e.g., juice box) and are capable of programming for association with specific phrases (e.g., "I would like some juice"). These types of devices are aimed at people with limited or no speech, which includes some people with ASD.

Many academic researchers have also created functional prototypes aimed at mobile devices. Common goals include help for language-communication skills (e.g., [25, 67, 70]), life/vocational-related skills (e.g., [23, 33, 75]), and social and emotional interaction (e.g., [17, 26, 56, 81]). In the following list, we highlight a few recent examples:

(a) *Help for language-communication skills*: Tang and Jheng [67] created iCan, which is a tablet-based system using the Picture Exchange Communication System (PECS). Traditional PECS are paper-based picture cards that describe an object, emotion, or action designed so that a non-verbal child can point to the picture card to communicate. They evaluated their system with 11 children with ASD and their caregivers over a 4-week period; they found that their system helped with image search which saved time. Additionally, their system had the advantageous ability to add audio to the picture cards.

(b) *Life/vocational-related skills*: Hayes and Hosaflook [33] created Hygiene Helper, which is a smartphone application (available for Android devices) aimed at helping teens learn about and track their daily hygiene. The authors had yet to evaluate their app with users at the time of their work's publication; however, their app had a fairly high 4.2/5 rating in the Google store.

(c) *Social and emotional interaction*: Fage [26] created a tablet-based application aimed at helping children self-regulate their emotions. Through a pilot study with 10 children (5 with ASD) over 3 months, use of the application was associated with a significant decrease in non-adaptive behaviors in the children with ASD. In a study that combined mobile app use and Google Glass, Washington et al. [81] developed a system to help with facial recognition. In a 3-month study with 14 families that had a child with ASD, the researchers found that their system could act as an effective training aid that often generalized when not using their app. However, results were highly dependent on the child's level of ASD. At the time of this writing, the authors were conducting a randomized controlled study.

[2]Many of the apps are designed for children, not necessarily focused on ASD.

Shared Active Surfaces. We used the definition established by Kientz et al. [37]; shared active surfaces are those that are "intended for multiple users in a co-located, mostly synchronous interaction, such as large displays, tabletop computers, electronic whiteboards, etc." (page 57). Commercial products in this category include Boardmaker online, which affords shared activities that support educational curriculums [15].[3]

Academic projects designed for shared active surfaces have focused on attaining skills aimed at several common goals, including social and emotional goals (e.g., [49, 87]), academic goals (e.g., [48]), and improving sensorimotor skills (e.g., [22]). In the following list, we highlight a few recent examples:

(a) *Social and emotional interaction*: Sharing experience via gaming can be an effective means for encouraging social interaction among peers [14]; consequently, games or game-like activities are common among prototypes that have leveraged shared active surfaces. For example, Zarin and Fallman [87] used participatory design techniques with six children diagnosed with either ASD or Down syndrome to create two tabletop games that encouraged social interaction.
(b) *Academic goals*: Picardo et al. [48] designed DTTAce for the Microsoft Surface; their software is a series of educational modules that use discrete trial training methods. Much like the DTT software for the PC, their program provides automatic data collection to help with tracking a student's progress.
(c) *Sensorimotor skills*: Cibrian [22] reported on using interactive surfaces to support music therapy aimed at improving sensorimotor synchronization through rhythm games. He ideated concepts through low-fidelity prototypes and used participatory design methods that included music therapists and children with ASD.

Virtual Reality. We defined *virtual reality* (VR) as designed experiences that are meant to simulate real-life experiences through 3D environments (including VR headsets) and/or interactions with 3D avatars. VR simulations have been found as an effective intervention for people with ASD because it can afford a safe environment for practicing and preparing for skills needed in a real-world environment [65]. Academic projects in VR have focused on life and vocational skills (e.g., [12, 74]), help with improving motor skills (e.g., [45, 46]), and social and emotional goals (e.g., [13, 24, 68, 88]). In the following list, we highlight a few recent examples:

(a) *Life/vocational-related skills*: Tzanavari et al. [74] evaluated a simulation that used a VR CAVE, which is an immersive 3D environment, to teach six children with ASD how to safely cross the street. They reported that the children learned the task in the simulation and were able to generalize their learning to a real-world environment. Bernardes et al. [12] created a serious VR game prototype using the Oculus Rift headset to help train people with ASD about how to use buses. They evaluated the usability of their game with five adults with ASD; however, at the time of writing, they had not yet evaluated whether in-game learning generalized to real-world experience.
(b) *Motor skills*: Mei et al. [45, 46] published two works in 2015 that compared customizable avatars to non-customizable avatars in VR motion-based games that were designed to improve hand-eye coordination. In their evaluation with 10 participants with ASD, they found that the customizable avatars were associated with improved performance and user experience [45, 46].
(c) *Social and emotional goals*: Ehrlich and Miller [24] created a series of 3D environments to help teenage students navigate through challenging school-related scenarios, some of

[3]Boardmaker Online and their other products also are designed for use on PCs and tablets.

which included social interactions. Tartaro et al. [68] described their evaluation of an author-able Virtual Peer (AVP) technology intended to help children practice and learn appropriate peer interaction through several scenarios that included taking turns, how to interrupt, and respond to teasing. In their evaluation with seven children with ASD, they found a significant improvement in how the children performed on the Social Responsiveness Scale, which measured reciprocity. Finally, in a very recent example, Zhang et al. [88] created and examined a collaborative virtual environment (called *CoMove*); the system was intended to encourage communication through solving collaborative puzzle games. The authors tested CoMove with 14 dyads that included neurotypical children ($n = 7$) and combined neurotypicals with children with ASD ($n = 7$). All of the children showed improvements in collaboration and communication after their study.

Robotics. The use of physical robots[4] for training/teaching people with ASD is a rapidly growing area; children with ASD have often demonstrated a preference for robotic toys over non-robotic toys [58]. A commercial effort by Robokind resulted in Milo, an affordable robot (about $5,000) capable of complex facial expressions and conversation [59]. Milo, like many of the academic efforts in this category (e.g., [42, 79, 80]), was designed to help children practice and engage in social interaction in a safe environment.

Many related academic projects have resulted in functional prototypes. For example, Salter et al. [61] reported on their development of QueBall, a spherical robot capable of five programs intended to teach emotions, color, and imitation, and encourage physical play. Other foci in robot/autism-related research have included assisting therapy [51] and promoting and assisting in self-care [36].

1.1.2 Academic Research on Mainstream Interactive Technologies for ASD Use. Academic researchers have also examined mainstream technologies for use with people with ASD. Examples in this category include the use of Minecraft and Reactable, a suite of music-making technologies.

Ringland et al. [57] presented a virtual ethnography exploring a Minecraft server dedicated for children with ASD, called *AutCraft*. Minecraft is a mining and building game that is popular among children. In their work, the authors argued that servers like AutCraft provide inclusive opportunities for children with ASD by creating a safe gaming environment free of cyber-bullying and predators.

Reactable [54] is a tangible user interface that requires players to move blocks into various locations on a table-top display to make music; a version is now available for mobile devices (iOS and Android). Villafuerte et al. [76] evaluated acquisition of social skills with nine children with ASD using a table-top version of Reactable; their findings indicated that participants displayed an increase in social interactive behaviors during sessions in which the product was used.

In summary, this background literature review emphasized the wide range of interactive technologies that have been created/used for meeting the heterogeneous abilities, interests, and challenges of children and adults with ASD. The technologies were designed for many different platforms and were aimed to address multiple challenges typical to ASD, including improving academic outcomes, increasing language and communication skills, teaching life/vocational-related skills, improving social and emotional abilities, reducing anxiety, and improving sensorimotor and motor skills. Further, this review is a small sample; the number of interactive technologies, both commercial and experimental, is rapidly proliferating. We argue that the proliferation of products and research aimed at ASD supports the need for studies like this aimed at examining how technologies are used, perceived, and discovered "in the wild." In the next section, we describe our methods.

[4]We categorized virtual robots (i.e., avatars) in the previous category.

2 METHODS

In our 2008 work [50], we used only surveys; however, surveys do not allow for conversational dialog, which we felt was needed as a first step because of the large expansion of possible technologies designed for ASD. We therefore modified our previous methods to initially include interviews to hone the survey questions that we used in this study. The interview and survey protocols were approved by DePaul University's internal review board; we have included the interview scripts in Appendix A. The branching survey is available online: https://www.surveymonkey.com/r/AutismTech. This project was funded by a small grant from DePaul's university research council. In the next sections, we present our participants (Section 2.1) and our data collection (Section 2.2) and analysis (Section 2.3) methods.

2.1 Participants

2.1.1 Interview Participants. We initially recruited 20 interview participants between June 2016 and February 2017. One participant canceled, resulting in 19 completed interviews with parents, teachers, and therapists who had children with ASD in their care. After completing the 19 interviews, we felt our questions were confirmed as needing very little modifications for the surveys; as such, we did not continue recruit interviewees, keeping our remaining budget allotted for as many survey responders as we could afford (i.e., survey sample size of 230).

Most (15) interviewees were women. Eight were parents, seven worked as special education teachers, One described herself as an applied developmental analysis and one was a speech-language pathologist (SLP). Two were both teachers who worked with typical and ASD children and were also parents of a child with ASD; for these latter two parents/teachers, we focused on their children rather than their students with ASD. The average age of the children of the parent participants was 9 years. The professional participants (teachers/therapists) had between 3 and 12 years of experience working with children with ASD. Table 1 presents more information about the interview participants.

Participants were recruited by reaching out directly through email to parent groups, teachers, and therapists, and contacts through social networks. Participants received a $50 gratuity for their participation. Thirteen of the interviews were conducted over the phone, and six were in person at a location of the participant's choosing. Most participants were located in the larger Chicago area (n = 14); one lived in Albuquerque, New Mexico, one in San Jose, California; and three in Milwaukee, Wisconsin.

2.1.2 Survey Participants. The online survey was available between July and October 2017. We offered a $10 gratuity with the caveat that we would review the open-ended questions to verify the validity of the answers; additionally, respondents were instructed that they had to complete at least 80% of the open-ended questions to receive the gratuity. We recruited survey respondents by posting links with an informational request on several related online forums focused on ASD. Additionally, when we sent the gratuity, we asked respondents to send the survey link to the appropriate people in their social networks.

Although we received 398 responses, we kept only 230. In other words, to achieve our maximum budgeted allowance of 230 responders, we reviewed responses as they were submitted to determine if they were at least 80% complete and open-ended questions were answered understandably. Once we achieved our maximum budgeted sample, we closed the survey. Among the 230 respondents, a large majority (219) were parents, seven were teachers, two were case managers who worked with several and two were therapists.

The only demographic information we collected from the parent responders was the age of the child they were responding to the survey for and their current location. The average age of the child

Table 1. Interview Participants

Participant	Pseudonym	Relationship to ASD	Age(s) Working with/or Child at Time of Interview
1	Anna	Special education	Grade school (kindergarten to 1st grade)
2	Jane	Special education	High school (9th to 12th grade)
3	Marylynn	Special education	High school (9th to 12th grade)
4	Cole	Special education	Grade school (kindergarten to 1st grade)
5	Kathy	Special education	Preschool (3 to 5 years)
6	Alyssa	Special education	Middle/High school (7th to 12th grade)
7	Tom	Special education	High school (9th to 12th grade)
8	Sam	Therapist (SLP)	18 months to 8 years
9	Renee	Therapist (ADA)	Younger than 3 years
10	Ray	Teacher/Parent	14 years (daughter)
11	Amanda	Teacher/Parent	14 years (son)
12	Mia	Parent	10 years (son)
13	Emma	Parent	9 years (daughter)
14	Laura	Parent	8 years (daughter)
15	Jayden	Parent	9 years (son)
16	Andrea	Parent	6 years (daughter)
17	Kayla	Parent	5 years (son—has a twin brother)
18	Susan	Parent	9 years (son)
19	Kimberly	Parent	6 years (son)

among the parents was 8.8 years (range 3 to 18 years, SD = 2.7 years). Participants responded from all over the United States; parent responders were from 38 different states, most from California ($n = 32$), New York ($n = 20$), Illinois ($n = 15$), and Texas ($n = 14$); therapists and teachers were from seven states, most from Illinois ($n = 6$).

Among the seven teachers, four described themselves as special education teachers; teachers had between 2 and 10 years of experience working with children with ASD. The average age of the focus child among the teachers was 11.1 years (range 7 to 16 years, SD = 3.8 years). The case managers and therapists had between 4 and 8 years of experience working with children with ASD. The average age of the focus child among the case managers and therapists was 7.0 years (range 4 to 13 years, SD = 4.5 years). Table 2 presents a summary of the professional (non-parent) respondents.

2.2 Data Collection

2.2.1 Interview Data Collection Methods. We started the interviews with teachers and therapists by asking about their careers, including the ages of children they worked with and how many years they had worked with children who had ASD. We then asked all participants to focus on one child with ASD. We transitioned the conversation toward details about the focus child, including age, school level, interests, their biggest current challenges, and challenges in which they had made progress and/or overcame. For parents, we also asked (when appropriate) about provisions in their child's Individual Education Plans (IEPs). In this work, however, we focused our findings from the latter portion of the interviews.

In the latter part of the interviews, we first asked about interactive technology use, such as what technologies and/or technology-based toys/games they had used to address challenges related to

Table 2. Professional (Non-Parent) Survey Respondents

Non-Parent Respondent ID	Relationship to ASD	Age(s) Working with/or Child at Time of Responding to Survey
236	General education	Grade school (1st to 4th grade)
237	Special education	Grade school (6 years)
238	Special education	Preschool (0 to 7 years)
239	Special education	Middle/High school (6th to 12th grade)
240	Special education	14 to 21 years
241	General education	High school (9th to 12th grade)
242	General education	Grade school (4th)
243	Therapist (SLP)	Case manager
244	Therapist (ADA)	Case manager
245	Teacher/Parent	Speech-language pathologist (SLP)
246	Teacher/Parent	Other (not specified)

ASD for their focus child. For each interactive technology used, we asked about their objectives, such as what ASD-related challenges were they trying to address. We then queried participants about perception of success. For instance, we asked about how effective the technology was for the focus child at addressing their objectives. To better understand information gathering, we asked about how they found the technologies they had used, and what they would have wanted to know about the technologies they had used prior to purchase and/or use. Additionally, we asked an open-ended question about what kinds of information would help them make informed decisions in the future about technologies and technology-based toys/games, followed by a list of potential attributes as prompts (e.g., price, age range, reviews) that we had created (we only used the prompts for attributes not mentioned by participants). Last, to understand perceived gaps, we asked a question from the 2008 work [50]: "In a perfect world, what type of interactive technologies would you like to see created to address your child's current goals or challenges?"

All interviews were audio recorded and later transcribed for analysis.

2.2.2 Survey Data Collection Methods. The survey began with a branching question that asked respondents to describe how they were answering the survey based on their relationship (i.e., parent, teacher, therapist, other) to children with ASD. The surveys then paralleled the interview questions with one exception: we used the question about interactive technology use to branch respondents to a different set of questions. For respondents who had not used any technologies for ASD, we asked them about their reasons for that decision (then asked the perfect world question). For respondents who had used technologies to address challenges associated with ASD, we asked them how many (up to five) they had used prior to asking the same questions about the interactive technologies and technology-based toys/games that we asked in the interviews. We followed this with the perfect world question.

2.3 Data Analysis

We began our analysis with three members of the research team individually inductively coding the interview transcripts using Atlas.ti; our work was guided by Saldana's [60] coding manual for qualitative researchers. We exported our codes as labels and adhered the labels to index cards. Using a card sorting method, we grouped our codes into categories and sub-categories, and agreed on category names and operational definitions. One team member summarized our agreed categories in a codebook.

Next, we each deductively re-coded the interview transcripts using the labels from the codebook and combined our Atlas.ti files; the combined files had a very high level of agreement because of our discussion. We did not conduct any statistical inter-rater reliability at this point because our deductive re-coding was not blind (i.e., it was the result of agreements and resolution of disagreements through discussion).

Using the interview codebook, one author deductively coded the open-ended survey responses. The author adapted the codebook by adding new codes for the non-use question (asked only of survey responders) and the perfect world question for topics not discussed in the interviews. Appendix B provides our final adapted codebook for the questions we are reporting on in this article.

Survey responses were analyzed using the adapted codebook: systematically, in which no inter-rater reliability was required, and interpretively, in which we conducted inter-rater reliability.

2.3.1 Systematic Coding (no Inter-Rater Reliability). We began the survey analysis with systematic coding (see Codebook Sections D.1 through D.3) for named technologies. We counted and tabulated the named technologies, their associated goals, and the effectiveness of the technology(s) at meeting identified goal(s); efficacy was assessed via Likert scale ratings in the surveys. We also systematically coded how survey respondents found the technologies they had reported (Codebook Section D.4).

We calculated the median for the Likert scale questions that asked respondents to rate the important information gathering via prompts (e.g. price, age range, reviews). We conducted a Friedman test to explore if there were statistically significant differences among the mean ranks.

2.3.2 Interpretive Coding (Inter-Rater Reliability Required). We used the adapted codebook to deductively analyze the three open-ended technology questions:

1. What would you have liked to have known about the product/service/toy/app before you tried it? See Codebook Section E.
2. What are your reason(s) for not using interactive technologies to address your child's challenges/goals? See Codebook Section F.
3. In a perfect world, what kinds of interactive technologies would you like to see created to address your child's challenges? See Codebook Section G.

To calculate inter-rater reliability for the open-ended survey responses, we created spreadsheets for each question. Respondent answers were placed in the first column and the codes/sub-codes from the codebook were placed in the top row. Two members of the team (other than the first author) then coded for the presence (binary) of each category. We used Cohen's kappa to determine reliability.

In this work, we reported only those categories that were agreed on with a kappa above .500 (good agreement) and coded for in at least 12% of the survey respondents by the two team members who completed the blind coding. We also included answer categories that were not commonly coded in the survey responses but that were salient in at least three (15%) of the interviews.

3 FINDINGS

We organized our findings into four sections paralleling the aims of the work: (1) descriptions of use, objectives, and success, such as what technologies/platforms teachers, parents, and therapists had used, the goals the technologies were aimed to address, and how they rated the effectiveness of the technologies at meeting their objectives; (2) information gathering, such as exploring how they discovered potential technologies and what they would have liked to have known prior to use; (3) non-use, such as what are reasons they had for not introducing interactive technologies to their children; and (4) desires, such as what did participants want designers to focus on in future technologies. In some cases, quotes from interviewees and responders were slightly edited for grammar and understanding.

3.1 Interactive Technologies Used

Survey respondents who reported using technologies (n = 136) described 83 different interactive technologies in which most (n = 63 (76%)) were designed for ASD. Our 19 interviewees told us about 77 different interactive technologies in which about half (n = 34 (44%)) were designed for ASD. Technologies were on a variety of platforms that included mobile devices (iOS, Android, Windows phone) and desktop computers (Mac and Windows); the desktop platform category included Web-based sites and older CD-ROM-based applications.

The technologies discussed were very diverse, resulting in very little overlap of shared experience; as such, we limited our list for this work to those products mentioned by at least two people among survey responders and interviewees (n = 23 products) (Table 3). All but one of the 23 common technologies were mobile apps. All were commercial (non-academic) products. Almost all (n = 22 (96%)) were designed specifically for ASD.

We also added information in the table about whether there was research/evidence from the Autism Speaks database [7]. According to the Autism Speaks site, "Anecdotal" = no specific research, "Research" = there are related studies but no direct research on the specific technology, and "Evidence" = specific research and evidence that the technology type is effective at achieving the intended goals.

In summary, there was almost no overlap among the reported technologies. Although our question about technologies used was very general (i.e., interactive technology), a majority of the common experiences were with mobile apps. Among the 23 technologies mentioned by at least two participants—22 of which were designed for ASD—the most common goals were related to language skills (n = 12) and communication (n = 10), social skills (n = 6), functional skills (n = 6), educational (n = 5), and scheduling and organization (n = 3). Although the Autism Speaks database is helpful, 5 of the technologies (22%) were not in the database; among the 18 that were in the database none were listed as having "evidence." Additionally, among the technologies that had listed ages, none were specified for children older than 12 years or were listed as a somewhat unrealistic "All ages."

3.2 Information Gathering

In this section, we detail how interviewees and survey respondents found the products they reported on (Section 3.2.1), what participants would have liked to have known prior to using and/or purchasing (Section 3.2.2), and what kinds of information (via prompts) they think they would find helpful prior to purchase/use (Section 3.3.3).

3.2.1 How Products Were Found. The most common way participants found technologies they had used was though the Internet and app store searches (survey respondents (n = 63), interviewees (n = 7)).

It was also very common for people to try products recommended by peers, family, and/or colleagues (35 survey respondents and 11 interviewees) in their social network (often through social media); in an example that also demonstrated more trust in social networks over searches, Kayla (a parent) told us:

> *I would think that most people I know, or moms I know, get most of their information on Facebook and Instagram and social media about what can be recommended. You don't just go to the app store, because that is useless . . . I think of it comes from reading special needs mom's blogs kind of things. Or I am on a couple of Facebook support*

Table 3. The 23 Commonly Mentioned (by at Least Two Participants) Interactive Technologies

Product	**Platform** (Mentioned)	**Goals for Use**	**Subjective Efficacy** (at Meeting Goals)	**Evidence** (Autism Speaks Database)	**Mentions** (How Many Interviewees/ Responders?)
Proloquo2Go AAC app	iOS Android	Language Communication	4.4/5	Anecdotal	10
What's the Word?	iOS Android	Language Educational	4.0/5	N/A (not in database)	6
Special Stories/ Special Words (Bundle of apps)	iOS	Communication Language Social skills Scheduling	2.75/5	No research	6
Learn with Rufus (Bundle of apps)	iOS	Communication Language Educational Functional skills	5.0/5	Research	5
Grace App (No longer available)	iOS	Communication	4.0/5	N/A (not in database)	5
Injini (Suite of apps)	iOS	Language Motor skills Educational	4.0/5	Anecdotal	4
Let's Learn Emotions	iOS	Social skills	4.5/5	N/A (not in database)	3
A Buzoo Story	Android	Communication Language	3.7/5	Anecdotal	3
Tobii Dynavox AAC app	iOS	Communication	2.0/5	Research	3
iSequences	iOS	Language Scheduling Functional skills	4.0/5	N/A (not in the database)	2
Go Sequencing	iOS	Scheduling Functional skills	5.0/5	N/A (not in the database)	2
Let Me Talk	iOS	Communication Social skills	4.5/5	Anecdotal	2
Match and Find	iOS	Communication Language Educational Functional skills	5.0/5	Anecdotal	2
Multiple Meanings Library	iOS	Communication Language	5.0/5	No research	2
Early Literacy Skills Builder	iOS	Communication Language	5.0/5	Research	2
Convey	iOS	Language Behavioral	5.0/5	Anecdotal	2
4kidcal	iOS	Functional skills	5.0/5	Anecdotal	2
Choiceworks	iOS	Motor skills Scheduling Functional skills	4.5/5	Research	2
Give Me Five!!!!	Android	Social skills	4.5/5	No research	2
Tap to Talk	iOS PC	Communication Language	4.5/5	Research	2
Look at Me	Android	Social skills	5.0/5	No research	2
Aaron	Windows phone	Communication	4.5/5	Anecdotal	2

Table 4. Reliability of Non-Prompted Information Seeking Categories (Codebook Section E)

Category	**Level of Inter-Rater Agreement:** Cohen's Kappa	**Sample Size** (That Raters Agreed to) **No. of Survey Responders (n = 136)**	**No. of Interviewees (n = 19)**
Product Information: Price	.844 (very good)	26 (19%)	0 (0 %)
Product Information: Free Trial	.844 (very good)	16 (12%)	0 (0 %)
Child Fit	.622 (good)	18 (13%)	19 (100%)

groups for parents of kids with autism . . . that is how information is shared . . . we will find like random tidbits of information but there is no general recommendation system, which would be a great thing to have.

Many survey respondents (n = 36) and interviewees (n = 8) also relied on professionals (i.e., teachers and therapists) for recommendations. For example, respondent 44 (a parent) tried "Let me talk" because "the medical pathologist of speech and communication recommended this app."

Nine of our interviewees discussed how trial and error was required, often leading to frustration. For example, Ray (a parent/teacher) said:

It just seems like a lot of them [apps], regardless of what you're looking for, there is such minimal information. Granted a lot of stuff I'm talking about is free stuff and I guess they figure you can always go and delete it. But it's a waste of time, and there have been times where I'll just skip it, because I don't want to download something that I'll just have to delete.

3.2.2 What Participants Would Have Liked to Have Known (Non-Prompted). Recall that two members of the team conducted inter-rater reliability for the presence of codes in the three open-ended questions in the surveys. We included three categories in which both raters agreed were present in at least 12% (16 of 136) of the survey answers with a moderate or better level of agreement using Cohen's kappa (Table 4).

When interviewees and survey respondents were asked an open-ended question about what they would have like to have known about the technologies they had tried prior to use, the most common unprompted answer from survey respondents was value-related product information; specifically, price (n = 26) and the availability of free trials (n = 16).

Other information participants desired was related to how good of a fit the product was for their child (survey respondents (n = 18), interviewees (n = 19)); "good-fit" included age range, alignment to their child's interests, and required abilities (e.g., reading level). In an example that included several good-fit attributes, Ray (a parent/teacher) told us:

I suppose that age, grade level, or like in the case of my daughter, her reading level or reading comprehension level. I suppose really age is helpful to point, then in other cases it's more like okay making it clear that this is the reading level age that this person is at . . .

Customization level was another commonly desired piece of information discussed by seven interviewees and five survey responders; expanding on his preceding answer, Ray (a teacher/parent) said:

The features like, how many different ways you can set up the touchscreen. How many options you have for customizing the layout of a screen, things of that nature. If it's programmable, how easy it is to program your own things into it.

Although not common among survey respondents, 10 of the Interviewees who were therapists and teachers also brought up desired evidence about the efficacy of the technologies. For example, Cole (a teacher) told us:

> *I want to see growth—effect. How did it effect the child? What did the child get out it? Was it one of those interactive things that they did not get anything out of it—or did they actually learn something from it?*

3.2.3 What Participants Would Have Liked to Have Known (Prompted). Following the open-ended question about desired information, we asked interviewees to respond to a list of informational categories as prompts (age, cognitive abilities, reviews, product goals, verbal abilities, and price); survey respondents rated the prompts' helpfulness (Likert scale of 1 to 5, where 1 was the least helpful).

The Likert median for all categories was rated as highly helpful (5 of 5). However, a Friedman test indicated that the information categories were rated significantly different, $\chi^2(5, N = 135) = 23.38$, $p < .001$ based on mean ranks. (This was likely due to the lower mean rank of price.) In the following sections, we included the survey Likert scale mean ranks with selected quotes about the prompts from the interviewees.

> *Appropriate age range (survey mean rank = 3.61).* Although age was considered highly important, interviewees often cautioned about the need to include other abilities because age can be a poor predictor of abilities when considering children with autism. For example, Tom (a teacher) told us:
>
> *I think age range would be tough for me to be most important. I think that again depends on the student. I think that I would recommend having that in there, but as someone looking at it, as an educator, I'd be much more concerned with reading level.*

Required cognitive abilities (survey mean rank = 3.61). Sam (a therapist) discussed the relationship of cognitive ability to customizability:

> *You know that cognitive [abilities are] a huge thing because if we have someone with severe neurological impairment, then obviously, we're going to have to make those communication modes very basic.*

Parent, teacher, and therapist comments and reviews (survey mean rank = 3.57). Reviews were very highly regarded by our interviewees when we suggested them as a prompt. However, it was also important to know the profile of the reviewer(s). For example, Jayden (a parent) said:

> *So [with reviews] we got somebody who hates something and someone who loves it, I'd be very curious to know, I'd want to know as a parent and a consumer that the reviews are authentic and that you are not as the presenter of the reviews, that you are not beholden in any way to anyone who's making anything.*

Sam (an SLP) added:

> *[F]rom a clinician perspective, I would say having some form of feedback from clinicians or educators would be helpful. I feel with a lot of these programs, depending for example, I'm assessing a communication device or communication program, a lot of the reviews or feedback that I'm going to receive are primarily from clinicians. We're not going to get much from families . . . are we really making sure that the feedback we're getting is useful in determining if that app is helpful to the child or if the child just enjoys looking at it? I think it's great to be able to separate the two types reviews.*

And Mia (a parent) felt that reviews and comments were . . .

> *. . . huge. Parents, educators, therapists, . . . maybe physicians although I feel [reviews would be most valuable from] mostly therapists.*

Goals that the parents/teachers/therapists had when using the technologies (survey mean rank = 3.57). Jayden (a parent) felt that goals and interest match were much more important than age range:

> *I think you go by interest and goal. Right if you have a deficit, if you have a goal that goal doesn't matter if that kid is an adult or four years old . . . It could be in the description that it was designed for instead of trying to sort it by age.*

Required verbal/reading abilities (survey mean rank = 3.54). Information about required reading/verbal abilities in product descriptions was somewhat controversial among two of the interviewees because of the difficultly parents might have in determining their own child's levels. For example, Jayden (a parent) told us:

> *I wouldn't put anything on there like that because I don't think the lay person is very good at figuring out what their kid's verbal abilities are.*

However, several other (n = 10) interviewees felt that it would be important to include reading levels. For example, Amanda (a parent/teacher) said:

> *"I think that would be important, especially if you have a non-verbal student/child, or one that has really low comprehension. I know that my son is at a 3rd grade reading level . . . I definitely think reading level would be helpful to know.*

Price (survey mean rank = 3.09). Although price was the most common non-prompted response among survey responders, it was ranked as the least important. Interviewees also discussed price as a less important part of the decision equation. For example, Ray (a parent/teacher) responded to our prompt about price by saying:

> *Yes. It would always be a consideration . . . but you would have to weigh that with what the benefit is going to be, and depends on what your need is.*

To summarize, most of our interviewees and survey responders found technologies through their social networks, from professionals (teachers and therapists), and by trial and error. When asked what they would have like to have known without prompts, interviewees highly valued reviews from peers and professionals, research supporting efficacy, customizability, and goals. Concerns about the fit of the product for their child was mostly discussed through prompts; age, reading level, and cognitive abilities were all received enthusiastically. Finally, although price was a common non-prompted response among survey responders, it was rated as the least important when compared to other prompts.

3.3 Non-Technology Use

In this section, we present the findings from the 82 survey respondents (all parents) who did not use technologies with their children (see Codebook Section F). We organized common answers into four common categories: (1) fear of negative effects (Section 3.3.1), (2) negative impressions (Section 3.3.2), (3) child's abilities/interest (Section 3.3.3), and (4) available products did not match needs (Section 3.3.4). We included the four categories in which both raters agreed were present in at least 12% (10 of 82) of the survey answers with a moderate or better level of agreement using Cohen's kappa (see Table 5).

Table 5. Interrater Reliability for Non-Use Categories (Survey Only—Codebook Section F)

Category	**Level of Inter-Rater Agreement:** Cohen's Kappa	**Sample Size** (That Raters Agreed to) **No. of Survey Responders (n = 82)**
Fear of the negative effects	.851 (very good)	21 (26%)
Negative impressions	.709 (good)	16 (20%)
Child's abilities/interest	.802 (very good)	13 (16%)
Did not match needs	.644 (good)	13 (16%)

3.3.1 Fear of Negative Effects. Twenty-one survey responders submitted that they feared that technologies would have a negative effect. We identified two common sub-categories: (1) technology is too isolating and removes people from potential peer relationships, and (2) technology will cause damage (non-specific):

(a) Sixteen respondents felt that technology leads to isolation, for instance, that technology was a barrier to communicating more with peers and other humans. A response coded for this sub-category included 182 who wrote, "[T]he most important thing for children is classmates and friends."
(b) Five respondents felt that technology would cause damage but were non-specific about the nature of that damage. For example, respondent 154 wrote, "I am worried that it will cause unpredictable damage to other aspects of the child."

3.3.2 Negative Impressions. Sixteen respondents held negative impressions about technologies. We identified three common sub-categories of sources of the negative impressions: (1) advice from social networks, (2) advice from experts (e.g., teachers, therapists), and (3) past bad experiences:

(a) Six respondents reported receiving advice from their social networks about the negative impacts of technologies. Responses coded for this sub-category included respondent 150, who wrote this: "My friend used a similar product, the effect is not very good, so I did not try."
(b) Six respondents also reported receiving advice from experts that technologies should be avoided. For example, respondent 195 wrote, "The doctor gave me some advice to keep kids out of contact with mobile phones, tablets and other electronic products, which can irritate their brains."
(c) Four respondents' bad past experiences (including that technologies induced fear) as their reasons for avoiding technologies. Respondents 173 wrote, "My child has a bad experience for an app, a horrible picture frightened him."

3.3.3 Child's Abilities/Interests. Among the 13 responses coded for this category, responders told us that their child was disinterested in technologies. This response often also included that the child was fearful of technologies. For example, respondent 162 wrote: "My child is not very interested in electronic products, he seems a little afraid."

3.3.4 Available Products Do Not Match Needs. Among the 13 responses coded for in this category, responders reflected that there were no available technology-based products that were well suited to their child's needs. For example, respondent 199 wrote, "At present, there are no suitable interactive technology products."

Table 6. Reliability for Desired Technologies Categories (Codebook Section G)

Category	Level of Inter-Rater Agreement: Cohen's Kappa	Sample Size (That Raters Agreed to)	
		No. of Survey Responders ($n = 230$)	No. of Interviewees ($n = 19$)
Considerations: Attributes/Features	.581 (good)	74 (32%)	2 (11%)
Technology platforms (non-app)	.676 (very good)	44 (19%)	1 (5%)
ASD Focus	.662 (very good)	41 (18%)	12 (63%)
General (more and/or better)	.546 (good)	39 (17%)	0 (0%)
Audience Focus	.804 (very good)	13 (6%)	3 (16%)

To summarize, parents who avoided technology use for their children were worried that the technologies might contribute to isolation; as such, non-digital interactions were preferred. Many respondents reported negative impressions about technologies that they had gathered from their social networks, professionals their children interacted with, and previous bad experiences. It was also common for respondents to report that their child was not interested and/or fearful of technologies, and that there were simply no products/services available that they felt were appropriate for their child.

3.4 Desires

In this section, we present findings from survey respondents and the interviewees when asked, "In a perfect world, what kinds of interactive technologies would you like to see created to address challenges of children with ASD?" We organized the most common answers into five categories: (1) attributes and/or features but not specific technologies (Section 3.4.1), (2) technology platforms (Section 3.4.2), (3) ASD foci products (Section 3.4.3), (4) general responses and non-specific responses (Section 3.4.4), and (5) audience focus (Section 3.4.5). Most responses were also coded into multiple sub-categories (see Codebook Section G).

We are reporting on four categories that both raters agreed were present in at least 12% (28 of 230 survey responses) of the survey answers with a moderate or better level of agreement using Cohen's kappa. We also included one answer category that was not commonly coded in the survey responses but that was coded in at least 15% ($n = 3$) of the interviews (Table 6).

3.4.1 Considerations: Attributes/Features. Most of the survey responders ($n = 74$) answered this question by listing considerations that designers should weigh. We identified four sub-categories: (1) audio and visual design; (2) attributes that designers should consider including interests, personalization, and customization; (3) experience considerations; and (4) availability:

(a) *Audio and visual design*: Raters agreed that 26 of the survey respondents included audio and visual recommendations in their descriptions of desired technologies. In an example that was also coded for customization (sub-category c) and ASD focus (category 3), respondent 190 (a parent) submitted:

> *An editorial software designed specifically for children with autism, children can write their own stories and make them into e-books, which can include text, photos, videos, music, and even voice recording . . .*

(b) *Consider children's interests*: Eight survey responders suggested that designers should consider an alignment to children's interest. In her interview, Susan (a parent) also suggested that alignment to her son's interests in sports would be valuable:

I guess it'd have to be something of interest for him . . . something for him to like read and like have to figure it out . . . it would have to catch his attention somehow, like only be about sports.

Consider personalization and customization: Ten survey respondents included customization and/or personalization. For example, respondent 20 (a parent) included:

[I]t would be an app that besides helping to develop a new skill should allow us parents to personalize it, so we can adapt the app to the requirements of our children and make the most of the benefits of the app.

(c) *Experience considerations*: We coded multiple responses as focusing on user experience; this included fun/enjoyable (n = 11) and intuitive/simple (n = 29). Four responses were coded for both, including the submission of respondent 9 (a parent):

[N]ot complicated, uses almost intuitive, I should not read much to know what it is, with well-defined purpose, and entertaining.

(d) *Availability*: Many responders were concerned with availability related to price/ affordability (n = 22) and/or platform availability (n = 17). In an example of the former, respondent 52 (a parent) stated:

[A]n app that helps to develop some skill, that is to focus on developing a skill, have audio, and at an affordable price.

3.4.2 Technology Platforms. We coded for this category area when participants described (non-app) technology platforms; these included robots and artificial intelligence (n = 28), 3D/4D simulations (n = 13), and wearable technologies (n = 10). Discussion of platforms was not common in the interviews.

Robots and/or agents with artificial intelligence were a common desire of survey respondents; people often suggested that the robots could become a friend such as in the submission of respondent 201 (a parent):

A robot that can become a friend with a child. And it can be customized into a child's favorite shape.

Simulated environments were another common survey submission. For example, respondent 138 (a parent) wrote:

Fairy tale world 3D virtual machine, so that autistic children in the favorite story characters, learn to communicate.

Several survey respondents discussed wearable technologies; respondent 167 (a parent) suggested:

A wearable device that allows children to maintain awareness and language training at any time.

Mia (a parent), in her interview, also suggested a wearable device aimed at helping to track her son when he wandered off (her response was also coded for ASD focus):

We definitely need a better way to track kids who might wander. And it needs to be inexpensive and it needs to be waterproof and it needs to be . . . on them all the time.

3.4.3 ASD Focus. We coded for this category area when participants mentioned a specific focus related to a challenge that is associated with ASD. This included technologies aimed at helping with social skills/communication, emotion identification, behavioral modifications, and organization and scheduling.

(a) *Social skills and communication*: The most common focus area in which both survey responders ($n = 26$) and interviewees ($n = 5$) suggested greater need was in social skills and communication. Jane (a teacher) wanted more video modeling technologies:

> *More video modeling for social interactions. [V]ideo modeling for how to handle a social interaction. It's best for students to be actually practicing social interaction but I think video modeling . . . [might help].*

Kayla (a parent) desired personalized social stories that her son could create himself:

> *[T]he ones that can feature him in a social story that is easy to build. Pictures of himself and his family and his classmates.*

Sam (a therapist) desired app-based games that facilitated turn taking and social interaction but stressed the need to collaborate with teachers and provide information about the evidence supporting the app:

> *We use a lot of just basic turn-taking games in our clinic, whether its Candyland or other interactive games, so finding some sort of simplistic, yet, reciprocal game that's on the iPad would be beneficial, especially if you could embed some of those language concepts of personal pronouns . . . I think the other thing too is just developing more apps that are more educationally relevant but a little bit more research based because I feel there's just such a plethora of apps out there that appear to be a good use of that resource when in reality they aren't.*
>
> *Researcher: When you say research based, what would you like to see that look like?*
>
> *Sam: I think just collaborating more with educators . . . rather than working with some software developer who decided yeah, let's do this cool app where we're looking at letters.*

(b) *Emotion identification*: Although this category has obvious overlap with social skills, we found that several survey respondents ($n = 26$) discussed the need for technologies aimed to help with identifying emotions. For example, respondent 200 (a parent) submitted an idea for a wearable:

> *Smart identification glasses, to help autistic people recognize faces, expressions, actions, etc.*

(c) *Behavior modification*: Eleven survey respondents and three interviewees desired technologies that helped with challenging behavior. When discussing ideal technologies for her son, Kimberly (a parent) told us:

> *Something to calm him down in public would be great.*

(d) *Scheduling and organizing*: Although not a common request by survey respondents, Tom, Marylyn, Anna (all teachers), and Renee (a therapist) wanted more technologies to support organization and scheduling. Tom suggested:

> *I would love to see a better organizer for students in the form of an app. I just think sometimes organization can be something that they struggle with . . . an academic planner app.*

Related, Marylyn told us:

> *So ideally having some sort of app that would help some of our students with autism kind of like schedule their day, and then be able to add in like things they need to do. And really just help them organize their day. That would be something really helpful.*

3.4.4 General—More, Better. Many (n = 55) survey responses were non-specific in (at least in part) of their answer, simply requesting more and/or "better" technologies aimed at ASD. For example, respondent 108 (a parent) submitted:

> *We need more high-quality apps and software.*

3.4.5 Audience Focus. Thirteen survey responses and three interviews were coded for audience concerns. One interviewee desired technology aimed at older children, and two discussed technologies aimed at helping to improve better communication/collaboration among the child's support group. Focusing on the latter, respondent 186 (a parent) submitted:

> *Hope to be able to easily communicate with autism experts, we provide the child's behavior and test results, experts give assessment and recommendations, visual video conferencing may be included, this process is completely free and efficient.*

The detailed response of Alyssa (a teacher) has many implications for design:

> *[I]t's less about tracking if a student had a good day, or how many prompts did they needed . . . and being able to send that information to either the teacher, who is the case manager, so they are able to track for an IEP goal, or even sent to a parent saying "hey, this is how they did in school today" . . . In theory, it could be some sort of tracking system that is just within the school system of an assistant or someone who is in the classroom with a student to be able to track things for the case manager.*

In summary, participants wanted technology designers and developers to consider attributes and features that included more audio and visual presentations, alignment to their child's interests, and greater abilities to customize and personalize. Participants also focused on the user experience (fun, intuitive) and easy availability. They also desired products on innovative platforms, including VR, robots, and wearable technologies. When considering ASD foci, participants discussed a need for products that help with social-communication skills, emotion identification, behavior modification, and scheduling/organization. Finally, it was common for participants to suggest that designers should also focus on a child's support network, such as design for better communication among parents, therapists, and teachers.

4 DISCUSSION

We organized the discussion of implications of this work following the aims the article: current technology use and perception among parents, teachers, and therapists who have children with ASD in their care; issues related to discoverability and information seeking about ASD technologies; and parent, teacher, and therapist desires for future directions in technology design for children with ASD. We conclude with limitations and future work.

4.1 Current Technology Use and Perception

In the 10 years since the publication of our last work [50], the number of available technologies and level of use has dramatically increased. In our earlier work, relatively few participants (25%) ever used any interactive technologies with their children, and only 7% of the interactive technologies they used were designed for ASD. In this current study, all 19 interviewees had used technologies, and about half of those technologies that we discussed (n = 34 (46%)) were designed to address ASD-related goals. A majority (59%) of survey responders had also used interactive technologies with their children, and about three quarters of the products submitted (n = 63 (76%)) were designed specifically to address ASD goals, resulting in a total of 97 mentioned ASD-focused interactive technologies. Together, these findings supported the assertion that technologies for ASD are both rapidly proliferating and increasingly are being adopted. Wider adoption of ASD-aimed technologies implies that there is a potentially growing and large enthusiastic audience for related academic research and projects.

However, participants chose technologies in an information-poor environment. This is due, in part, to a lack of efficacy-based research on most current commercial offerings. In further support of the paucity of available research on the efficacy of ASD technologies, we investigated the 23 products mentioned by at least two participants on the Autism Speaks database. None were categorized as "evidence"; recall "evidence" meant that there was specific research and evidence that the technology type is effective at achieving the intended goals. And only four (17%) were categorized as having been "researched"; recall "researched" meant there are related studies but no direct research on the specific technology. The remaining were listed as having "no research," were not in the database, or only supported by "anecdotal research." The lack of information about efficacy of commercial technologies is not unique to ASD.

In a 2016 article, Anthes [9] discussed how very few of the smartphone apps designed for mental health have any research supporting their efficacy. As a response, the American Psychiatric Association (APA) created a Smartphone App Evaluation Task Force [3], that led to a multidimensional evaluation framework aimed at helping psychiatrists share and gather information about mental health smartphone apps. The framework considers safety/privacy concerns, evidence (i.e., effectiveness), ease of use, and level of interoperability with other systems (e.g., medical record systems). To achieve the goals of the task force, psychiatrists are expected to rate apps on each dimension and then contribute their evaluations to an information sharing resource. In an early investigation to assess the inter-rater reliability potential among contributing psychiatrists, Tourus et al. [72] asked five psychiatrists to submit evaluations of three apps designed for depression to the sharing resource. The researchers found a very high level of reliability among their participating psychiatrists, indicating promise for their proposed framework.

In related ASD research, Fletcher-Watson [27] worked to address the lack of evidence of efficacy of ASD-aimed technologies with a series of technology reviews in 2013. In later work [28], she discussed potential paths that academic researchers could take to evaluate technologies designed for ASD; one suggestion was for conducting random-controlled experiments of commercial products.

In consideration of Fletcher-Watson's advice, we argue that researchers should consider leveraging the APA's approach and framework for analyzing ASD technologies. This would require lab studies specifically aimed at experimental design studies focused on efficacy by assessing and comparing commercially available products aimed at ASD-related goals, and usability studies to explore ease of use stratified by child attributes (e.g., age and abilities). How this information might be shared is a challenge related to discoverability and information seeking.

4.2 Discoverability and Information Seeking

Although all of the products our participants discussed were commercial and most were designed for iOS, the products mentioned had minimal overlap. Only 22 (23%) of the ASD-focused technologies were mentioned by at least two participants; the remaining (n = 75) were mentioned by only one participant. This finding demonstrated that although ASD-related technologies are more widely used and have proliferated at a rapid pace in the past 10 years, there does not appear to be much unanimity among available choices. We hypothesized that this was due in part to the limitations of current information seeking methods and sources. In other words, although there are many choices available, our participants had very little knowledge about the extent of their potential choices.

The most common reported discovery method was through searches on app stores and the Internet (45% of those who used technologies), followed by recommendations from their social networks and social media (30%), and professional recommendations (25%). However, several (47%) of our interview participants explained that their searches for finding effective and appropriate technologies relied on a lot of trial and error; this in turn often led to dissatisfaction on the part of the child and time wasted at their expense. Together, these findings support the need for a crowdsourced information sharing resource that could provide recommendations to aid discovery and increase the likelihood of a good fit for a child. An effective sharing resource, such as a recommender system incorporating both the preferences and needs of the children, could potentially reduce these frustrations by leveraging the opinions of similar users. Connecting this concept back to the previous sections (current use and perception), a sharing resource should also include findings from lab studies (i.e., experimental and usability studies).

The types of information people told us they desired prior to using a technology with their child had several implications for the design for such a recommendation system. Unprompted, people were most often concerned about price and how good of a fit the product was for their child; "good-fit"' included age range, alignment to their child's interests, and required abilities (e.g., reading level). The availability of free trials and the level of customization (i.e., adaptation for a range of children) were also common unprompted responses.

When given a list of potential types of information as prompts, survey respondents ranked child attributes (age, cognitive and reading levels) and reviews from other parents/teachers/therapists as the most important. Goals that the technologies purported to address was also highly ranked. Together, these findings indicated that a helpful information sharing system should consider inputs about child attributes and goals, and provide recommendations about matching technologies that include price, reviews, customization level, and availability of free trials. Although we found that the Autism Speaks database was a good resource for background information about ASD-related technologies, it provided limited information that appeared to be scraped from manufacturers' Web sites.

In our review looking for similar information sharing resources beyond the Autism Speaks database, we found two additional resources: (1) bridging apps [18] and (2) a recommender for searching iOS apps called *i.AM Search* [34]; the latter has not been available since 2012. Bridging apps is a Web-based filtering tool aimed at helping people discover apps and read reviews for all disabilities (not just autism). It is unclear how the tool's database is populated, and there is no mechanism for users to add their own opinions. Owned by Wynsum Arts, i.Am Search was founded by a mother of a child with ASD who was frustrated by the overwhelming number of apps designed for ASD available at the iTunes store. The app relied on suggestions provided by their "team of experts." The motivation for both of these tools is an indication of the need for sharing systems aimed at discoverability; however, we argue that given the heterogeneity of ASD, a "team of experts" cannot scale in the same way a crowdsourced system might. It is also possible that an information sharing resource might encourage parents who reported non-use to try some available technologies.

To be clear, although we are technologists, we are not advocating for interactive technologies as a panacea, nor do we believe that they are appropriate for all children. However, given that the most common two reasons (fear of negative effects and negative impressions) were largely based on non-direct experience, an information sharing resource of others' experiences that included information about efficacy and usability might also be useful to those who have not tried interactive technologies to address some of their children's goals.

4.3 Desires

Among the 23 technologies mentioned by at least two participants, the most common goals were related to language skills (n = 12) and communication (n = 10), social skills (n = 6), functional skills (n = 6), educational/math (n = 5), and scheduling and organization (n = 3). The goals of these products almost perfectly aligned with the 2008 findings [50] from the open-ended question about what participants desired in interactive technologies. In the 2008 study, respondents focused on improving three skill areas: academic, social/communication, and organization. When asked about desires in this this study, our list expanded. Three new areas of focus were common: (1) help with emotion identification; (2) ways to modify challenging behaviors; and (3) help for the children's support systems, including facilitating better behavior tracking and communication among the members of support systems. The latter three foci were not mentioned as goals of use for the 23 common commercial ASD-focused technologies indicating potential gaps in available technologies and implications for design of new technologies.

In this study, we also collected data on participants' desires related to attributes/features and desired platforms that also have implications for future technology design. Participants suggested that designers focus on incorporating audio and video. Additionally, it was suggested that designers consider common child interests and allow for a high level of personalization and customization. Experience considerations, such as enjoyable and intuitive, were also commonly expressed as important. Several experimental platforms were suggested that included robots and artificial intelligence, simulated environments, and wearables.

Findings related to desires also had implications for academic researchers. Specifically, although many academic projects resulted in functional prototypes aimed at common desired goals and platforms, not a single interviewee or survey participant had ever been involved in an academic project. And although our literature review represented a small portion of academic work, much of it was aimed at creating functional prototypes aimed at addressing multiple challenges our interviewees, and respondents told us they desired improving academic outcomes (examples in academic research [48, 82]), increasing language and communication skills (examples in academic research [47, 67]), and improving social and emotional abilities (examples in academic research [1, 81]). In other words, many of the desired technology attributes, features, and foci that participants discussed have already been (or are being) explored in academic work. However, most of our participants were unaware of the massive body of research work.

We argue that an information sharing resource such as the one we proposed could also be a potential platform for academics to increase outreach—that is, to recruit participants for their functional prototypes (prior to public release), solving two problems: (1) for potential participants, a larger pool of free, and possibly paid, opportunities to find experimental technologies that might ameliorate some of their child's challenges, and (2) for researchers, an opportunity to work with larger and more diverse participant groups.

To summarize, the desires of our participants had several implications for what technologists might consider, including diverse platforms (e.g., robots, VR) with more consideration given to personalization, customization, and incorporation of audio and video. Our findings also supported a need for a crowdsourced information sharing system that leverages the APA framework for providing recommendations about ASD technologies for parents, teachers, and therapists. In our envisioned system, academic researchers would be encouraged to contribute by conducting lab studies (i.e., experimental design and usability studies of commercial products). The system could also potentially help academic researchers with outreach to wider audiences. In turn, parents, teachers, and therapists would be encouraged to contribute their own experience through reviews. Findings indicated that an information sharing system should filter products based on the following:

- Child attributes (interests, abilities, age)
- Options for customizability and personalization
- Goals and challenges
- Platform
- Reviewer profiles.

4.4 Limitations and Future Work

There are several limitations of this work; some are common to survey-based research, including self-selection bias and an inability to discuss issues in depth. Additionally, it is probable that survey respondents used many more technologies than they listed but satisficed on the number they were willing to write about. Although we had a very good representation of participants from around the United States, they were all limited to the United States. For instance, we did not have any representation from other countries. Limitations of the interviews included a relatively low sample size and that participation was largely limited to the Chicago area.

This study was also limited by the non-inclusion of people with ASD. Although young children are not appropriate for recall studies like this, discussions about technology use with older children and young adults will be an important addition in future work.

Additionally, as in all survey and interview work, the data relied on people's memory of software use. To address this last concern, we plan on conducting diary studies in which we will load the higher-rated iOS software on iPads that participants told us about and ask participants to report (via an online survey) their child's (or children for teachers) use experience.

Other future work will include lab (experimental design and usability) studies to compare commercial products aimed at similar goals to help build a database of evidence-based technologies for parents, teachers, and therapists to choose from. Together, the diary and lab studies will move us closer to our vision of an information sharing system that can provide evidence-based recommendations for adults and children with ASD, their supporting networks, and academic researchers interested in exploring technologies designed for ASD.

APPENDICES

APPENDIX A: INTERVIEW SCRIPTS

Parent Script

This conversation is being recorded for research purposes. You may request that the recording stop at any time.

---Introduce yourself here → "We are exploring interactive technologies designed for children who have autism" >

Tell me about your child? We can use his/her name–but I will change it to a pseudonym when I write about this project.

—Probe for age

What are your child's interests?

What are your child's (current) biggest challenges? In other words, what are his/her current goals?

---If in school–ask: → We know that many schools categorize children into three levels of autism. Does your school do this? Can you tell me what level <Name/your child> is categorized?

-----Does your child have an IEP?

-----Can you tell me about provisions that are in his/her IEP? >

Tell me about a past challenge in which <Name/your child> has made a lot of progress.

Did you use any interactive technology-based products or toys aimed at [challenge 1]?

Probe for apps/software/toys etc. For each one named–ask:

- Do you think it was effective at addressing [the challenge]?
  - Why/why not
- How did you find this product?

Was there anything that you would have liked to have known about the product before you tried it?

If yes –> tell me about that.

Have you used any other interactive technology-based products/toys with your child?
Probe for apps/software/toys etc. For each one named–ask:

- What was your goal for using that product? (Note: this may just be for entertainment)
- Do you think it was effective at addressing [the goal]?
  - Why/why not

Was there anything that you would have liked to have known about the product before you tried it?

If yes–tell me about that.

In a perfect world, what kinds of interactive technologies would you like to see created to address your child's current goals/challenges?

What types of information would you like to have about those technologies before you try them?
---transition "*those are great ideas. I would like to get your impression of some other information we are curious about.*" How important would you find the following information (only include ones not mentioned):

- Parent/educator comments and reviews
- Goals that the parents/educators had when using the technologies and how well the technologies met those goals
- Age range
- Required verbal abilities
- Required cognitive abilities
- Price
- Their child's interests

Do you have any questions for me?

Teacher Script
This conversation is being recorded for research purposes. Please let me know now if you do not agree to being recorded. You may request that the recording stop at any time.
---Introduce yourself here → "We are exploring interactive technologies designed for children who have autism" >
Tell me a little about your career as an educator?

- Probe for number of years teaching
- Ages taught
- Number of years working with children who had autism.

How does your school assess a student's level of autism?

---Probe for tests used

Now, I want you to focus on a single student you have had with autism (we can use a pseudonym–if you do use the child’s name, I will change it in the transcript)

- Probe for age/grade
- What was your interaction with that student?

[REMAINING INTERVIEW WAS THE SAME AS FOR PARENTS]

Therapist Script–V1

This conversation is being recorded for research purposes. Please let me know now if you do not agree to being recorded. You may request that the recording stop at any time.

---Introduce yourself here → “We are exploring interactive technologies designed for children who have autism” >

Tell me a little about your career as a speech language pathologist (or occupational therapist)?

- Probe for number of years
- Ages of children worked with
- Number of years working with children who had autism.

Have you ever been involved with assessing a child’s level of autism?

---Probe for tests used

Now, I want you to focus on a single client you have had with autism (we can use a pseudonym - if you do use the child’s name I will change it in the transcript)

- Probe for age/grade
- What was your interaction with that student?

[REMAINING INTERVIEW WAS THE SAME AS FOR PARENTS]

APPENDIX B: ADAPTED COMBINED CODEBOOK: INTERVIEWS AND SURVEYS

This codebook *only* contains codes relevant to the article and represents a subset of the larger codebook. Additionally, not all the codes were reported on in the article because they did not reach the level of salience that we agreed upon.

Attribute Coding (No Inter-Rater Reliability)

A. Attributes of Interview Participants and Respondents

A.1 Attribute: Teacher
Code when participant is a teacher or teaching assistant that works with children with autism

A.2 Attribute: Teacher/Therapist
Code when participant serves in a dual role as teacher and therapist

A.3 Attribute: Parent
Code when participant is a parent of a child with autism

A.4 Attribute: Parent/Teacher
Code when participant is a teacher that works with children with autism and is a parent of a child with autism

B. Child Bio–Attributes of the Focus Child

B.1 Child Bio: Age
Code when participant states their child's current age (typically parents) or age when he/she worked with the child (typically teachers /therapists).

B.2 Child Bio: School: grade

C. Professionals: Attributes

C.1 Teaching Experience: Grades/Ages Taught
Code when participant (specifically teacher) discusses the grades and/or ages of students that he/she has and/or currently taught.

C.2 Teaching Experience: Years
Code when participant (specifically teacher) discusses the number of years of experience he/she had as a teacher.

C.3 Therapist Experience
Code when participant discussed any information about clients/ population that he/she had worked with.

C.4 Therapist Experience: Years
Code when participant (specifically teacher) discussed the number of years of experience he/she had as a teacher.

Systematic Coding (no Inter-rater reliability)

D. Technologies Used

D.1 Specific Technology: [specify name]
Code when participant mentions a specific technology name (i.e., name of app, software program), also specify platform and the purpose/goal with each specific technology.

D.2 Technology: Platform
Code when participant mentions a specific technology device.

D.2.1 Technology: Platform: AAC Device
D.2.2 Technology: Platform: Gaming System: [specify system]
D.2.3 Technology: Platform: iPad/Tablet/Mobile: [specify operating system]
D.2.4 Technology: Platform: Web Based
D.2.5 Technology: Platform: Computer

D.3 Technology Used: Purpose/Goal

D.3.1 Technology: Purpose/Goal: Academics
Code when participant discusses a technology's purpose or goal related to improving skills in the area of academic content such as working on numbers, reading, or maps.

D.3.2 Technology: Purpose/Goal: ADL–activities of daily living/functional skills
Code when participant discusses a technology's purpose or goal related to improving skills in the area of activities of daily living such as bathroom etiquette, feeding or dressing oneself.

D.3.3 Technology: Purpose/Goal: Emotional /Behavioral
Code when participant discusses a technology's purpose or goal related to improving skills in the area of emotional and behavioral content such as working on emotion identification, decreasing non-functional behaviors, and appropriate emotional expression.

D.3.4 Technology: Purpose/Goal: Entertainment
Code when participant discusses a technology's purpose or goal related as strictly entertainment.

D.3.5 Technology: Purpose/Goal: Fine Motor/Motor Skills
Code when participant discusses a technology's purpose or goal related to improving fine and gross motor skills such as working on pincer grasp, individual finger movement, and gross motor control (i.e., arms, legs).

D.3.6 Technology: Purpose/Goal: Independence
Code when participant discusses a technology's purpose or goal related to improving independence.

D.3.7 Technology: Purpose/Goal: Rigidity
Code when participant discusses a technology's purpose or goal related to decreasing rigidity such as working on increasing flexibility and appropriately responding to change.

D.3.8 Technology: Purpose/Goal: Scheduling
Code when participant discusses a technology's purpose or goal related to scheduling. This could refer to a scheduler for the child or the adult (parent/teacher/therapist).

D.3.9 Technology: Purpose/Goal: Sensory
Code when participant discusses a technology's purpose or goal related to improving skills in the area of sensory content such as working on decreasing sensory sensitivities.

D.3.10 Technology: Purpose/Goal: Social/Communication
Code when participant discusses a technology's purpose or goal related to improving skills in the area of social and communication content such as working on appropriate social interactions, social stories, expressive and written communication, and online communities.

D.3.11 Technology: Purpose/Goal: Transitions
Code when participant discusses a technology's purpose or goal related to improving transitions such as pictures or text explaining what will happen next.

D.4 Technology Used: How Found?

D.4.1 Online
Code when participant/respondent found technology through an Internet search or apps store searches.

D.4.2 Social Network
Code when participant discusses learning about a technology from his/her social network(s) (i.e., family, friends and colleagues).

D.4.3 Teachers
Code when a parent participant discusses learning about a technology from their child's teacher(s).

D.4.4 Therapist
Code when parent participant discusses learning about a technology from their child's therapist.

D.4.5 Trial and Error
Code when participant discusses learning about a technology through trial and error (i.e., trying different technologies on their own and keeping the ones that work and deleting ones that do not).

D.5 Technology: Desired Knowledge–Explicitly Asked (asked as Likert in the survey)

D.5.1 Technology: Desired Knowledge: (Explicitly Asked): Age Range
D.5.2 Technology: Desired Knowledge: (Explicitly Asked): Goals for Use
D.5.3 Technology: Desired Knowledge: (Explicitly Asked): Price
D.5.4 Technology: Desired Knowledge: (Explicitly Asked): Reviews
D.5.5 Technology: Desired Knowledge: (Explicitly Asked): Cognitive Abilities
D.5.6 Technology: Desired Knowledge: (Explicitly Asked): Verbal Abilities

Interpretive Coding (inter-rater reliability conducted for surveys)

We coded three questions for this article that required inter-rater reliability.

- E. Information Gathering: What I would have liked to have known about tech prior to use (non-prompted)
- F. Non-use: Why I do not use technologies with my child
- G. Perfect world: What kinds of tech would you want for your child

E. Information Gathering: What i would have liked to have known about the product before trying

E.1 Child Fit

Code if participants wanted more information related to the fit of the product for their child. We identified six sub-categories:

E.1.1 Required skills to use
E.1.2 Is it age appropriate (tone appropriate)?
E.1.3 Is it effective/helpful?
E.1.4 Is it safe?
E.1.5 Is it made for children with ASD?
E.1.6 Will my child take interest?

E.2 Product Capabilities/Limitations

Code if participants wanted more information about what the product can do–what it afforded (and what it did not). We identified four sub-categories:

E.2.1 Customizability options?
E.2.2 How comprehensive?
E.2.3 Product limitations
E.2.4 Evidence of effectiveness

E.3 Product info

Code if participants wanted just more information about the product prior to use that was not related to capabilities. We identified five sub-categories:

E.3.1 How to make the best/most of/better instructions
E.3.2 No ads?
E.3.3 Platform(s) related
E.3.4 Price related/value
E.3.5 Free demo/trial

E.4 Recommendations

Code if participants desired recommendations from other parents or information about how valuable the technology was for them. We identified two sub-categories:

E.4.1 Other parent recommendations/comments/reviews
E.4.2 How easy/valuable it was/wished I would have known about it sooner

E.5 Additional Related Information

Code this for information that is tangentially related to the product. We identified three sub-categories:

E.5.1 Is there a related website?
E.5.2 Are there versions?
E.5.3 Who were the creators dev team?

E.6 Nothing More Needed

Code when the respondent reports that they did not need any additional information (but not if he/she left it blank or wrote N/A). This was only relevant for survey responses.

F Reasons for not using technologies

Asked only of survey responders

F.1 Bad Product Match

Code when the focus of the reason is about the belief that there are no good products available and/or they are overly complicated and/or too expensive. We identified three sub-categories:

F.1.1 Does not work/will not help
F.1.2 No perfect/good products available (e.g., overly complicated)
F.1.3 They are too expensive

F.2 Child Ability/interest

Code when the focus of the reason is due to the child's abilities/interest. We identified three sub-categories:

F.2.1 Child is disinterested and/or fearful
F.2.2 Child is not capable
F.2.3 Child is too young

F.3 Child: Will Have a Negative Effect

Code when the reason has to do with the belief that using technologies will have a negative effect on the child. We identified four sub-categories:

F.3.1 Child needs more exercise–Tech will promote sitting
F.3.2 Child needs to communicate/play more with people/children: Tech will increase isolation
F.3.3 Tech will cause some unspecific damage
F.3.4 Concerns about the child obsessing about the tech

F.4 Negative Impressions

Code when a parent respondent received negative information about technology from family, friends, professionals, and/or schools. Also code when there was a reported bad past experience and/or he/she did not trust or see the need for tech. We identified four sub-categories:

F.4.1 General: Lack of trust in tech/no need
F.4.2 Past bad experience(s) (e.g., led to disruptive behavior)
F.4.3 Negative advice from social network (family, friends)
F.4.4 Negative advice from professionals/school/IEP provisions

F.5 Traditional Methods Preferred

Code when respondent's answer is related to a preference for relying on professionals and/or parental interaction.

F.6 Need More Information

Code when respondent felt he/she did not have the information they needed to make good decisions.

G Perfect World

G.1 Attributes/Features

Code when respondent describes an aspect or feature of the technology he/she desire but not the technology itself. We identified four sub-categories that had further sub-categories:

- G.1.1 Should consider (design):
  - G.1.1a Visual concerns/recommendations (text/colors)
  - G.1.2b Audio/Music concerns/recommendations
- G.1.2 Should include:
  - G.1.2a Integration of child's interests
  - G.1.2b Integration of multiple goals
  - G.1.2c Clear goals/aimed at teaching something specific
  - G.1.2d Means for children to share their work
  - G.1.2e Customization/progressive scaffolding: By parent and/or child and/or self-adjusting to meet child's needs
  - G.1.2f Help for parents and/or teachers (suggestions for use)
  - G.1.2g Facilitate collaboration with parents/teachers/therapists
- G.1.3 Should be: Experience related:
  - G.1.3a Fun/enjoyable/interesting
  - G.1.3b Intuitive/simple
- G.1.4 Should be: Availability related:
  - G.1.4a Inexpensive/affordable/ability to demo
  - G.1.4b Available on many and/or specific platforms

G.2 Audience Focus

Code when they mention design for specific sub-audience within the ASD community. We identified two sub-categories:

- G.2.1 Design for parents and teachers
- G.2.2 Design for older children/young adults

G.3 Desired Creators

Code when respondent wants to see more technologies by experts/specialists and/or when he/she want to see more focus on technologies that are supported by research.

G.4 Desired Technologies Platforms

Code when respondent mentions specific technologies platforms. We identified five sub-categories:

- G.4.1. 3D/4D interactivity/simulations
- G.4.2. Robots/friend and/or replacement/augmentation to parent/teacher/therapist
- G.4.3. AI to facilitate/help with communication
- G.4.4. Virtual rehabilitation
- G.4.5. Wearables (e.g., glasses/headsets)

G.5 Focus of the Technologies (ASD)

Code when the respondent mentions a SPECIFIC focus related to ASD. This has overlap with G.6 (purpose). The difference with purpose is not specifically aimed at a common ASD challenge. We identified seven sub-categories:

- G.5.1. Academics (e.g., reading, math)
- G.5.2. Emotional/Behavior
- G.5.3. Scheduling/Organizer
- G.5.4. Social skill/Communication
- G.5.5. Transitioning

G.5.6. Functional skills
G.5.7. Motor skills/exercise
G.5.8. Sleep disorders
G.5.9. Modeling/Social stories

G.6 Purpose of the Technology
Code when respondent mentions a specific purpose. This has obvious overlap with attributes (G.1); in this case, code for a specific rationale rather than a "should have/be:"
G.6.1. App to motivate tech use
G.6.2. Make the child "normal"/"Fix" them
G.6.3. Portal for parents/help for finding technologies/sharing info
G.6.4. Track child's skills/progression

G.7 General Comments Asking for More/Better/Interesting Technologies
Code when respondent wants to see more technologies by experts/specialists and/or when he/she desires more focus on technologies that are supported by research.

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