Designing Interactive Technology to Support Children with Autism

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Figure 1: (Left) MaskMe: Wearable Masks to Support Children with Autism Engage in Social Greeting. (Middle) MagicBLOCKS: Interactive Tabletop to help Therapists in Training Children with Autism with Cognitive Ability. (Right) Tidd: Augmented Tabletop Interaction Supports Children with Autism in Training Daily Living Skills.

ABSTRACT

This study aims to investigate the design of interactive technologies to support the development of greetings, peer socialization, and daily life skills in autistic children. Collaboration with professional therapists and families is integral to ensure that the designed technological tools align with practical needs and undergo effectiveness evaluations. The research content includes 1) wearable masks for training autistic children in social greetings, 2) tabletop augmented reality technology to aid therapists in training children in audience socialization, and 3) tabletop interactivity to assist autistic children in learning daily activities such as making beds and dressing. The findings of those studies are expected to provide substantial guidance for developing interactive technologies that support social interaction and daily life skills development in children with autism. By using three different technologies, my doctoral research will provide a deep understanding of how interactive technologies can benefit the development of autistic children in diverse areas.

CCS CONCEPTS

• **Human-centered computing → Accessibility design and evaluation methods**.

KEYWORDS

Inclusive designs, Children with autism, Assistive technology, Autism intervention

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1 INTRODUCTION

Researchers and clinicians commonly define autism as a pervasive neurodevelopmental condition characterized by challenges in social communication, language comprehension and expression, as well as the presence of restricting and repetitive behaviors, interests, or activities [3, 14]. Based on data from 2020, the CDC reported that approximately 1 in 36 children in the U.S. is diagnosed with an autism spectrum disorder (ASD) as of 2023 [20]. Due to arbitrary categorization and a lack of inclusive understanding, individuals with autism are often labelled with an identity and a disability [2, 5]. This labelling places them at a heightened risk of experiencing stigma, bullying, isolation, and even facing the risk of suicide in their daily lives [11, 16]. Children with early-stage autism can benefit from intervention training focusing on life skills. It demands enormous human and financial resources, posing difficulties and hardships for families of autistic children [19]. Interactive technology offers new opportunities in the digital interventions field; however, research gaps persist, necessitating further exploration of how to design and apply these technologies to support children with autism. The use of assistive technology for intervention and assessment of children with autism has been demonstrated by previous researchers [26, 28].

The results indicate that emerging assistive technology can be beneficial in training children with autism in daily activities, social interaction, language learning, and overall well-being. I aim to develop a deeper understanding of the real-world requirements for technology from people with autism and other stakeholders. Then, utilize this as inspiration to build related technologies that assist individuals with autism in communicating. I expect that the technologies I develop will assist therapists in autistic institutes in teaching social skills to children with autism. As well as helping parents train life skills for children with autism. My PhD thesis investigated the following research questions:

- RQ 1: What are the challenges and opportunities associated with distance learning for supporting children with autism and their stakeholders?
- RQ 2: How can assistive technology effectively aid caregivers' and therapists' intervention in children with autism?
- RQ 3: How can technology be utilized to support experts in early screening and diagnosis of children with autism?

In this doctoral consortium, I focus on RQ2, presenting three interactive technology proposals to enhance social interaction and daily live skills practice for children with autism, please see Figure 1. My current work seeks to bridge the gap in autism intervention methodologies by focusing on enhancing peer socialization, cognitive training, social greetings, and the daily life skills of autistic children. I expect to make the following contributions: (1) Understanding the needs of therapists and family caregivers in training daily skills of children with autism. (2) Using the design principles of this study to understand the technical implications of interventions that allow assistive technology to support children with autism. (3) Empirically validating the effectiveness of the three technologies proposed in this study to support the social and daily life skills of children with autism. (4) Promote positive outcomes for children with autism through these validated interventions. Achieving these goals will not only enhance understanding of autism interventions but also allow the development of more nuanced support systems. It is expected that this research will play an essential role in developing effective intervention strategies, ultimately creating a more inclusive and supportive environment.

2 BACKGROUND AND RELATED WORK

Medical models portray autism as a disorder requiring medical treatment and repair for a person to integrate into the dominant society [26]. And the social model has led to accessibility considerations being part of policymaking in areas such as education, work, and website development [22]. My research framework for this study was a support therapist in social training and daily living skills for children in a rehabilitation center. The importance of independent life for people with autism lies in creating a more independent and autonomous lifestyle for them [15]. Fostering independence in life is critical to their growth and development. By mastering daily living skills such as self-care, social skills, time management and decision-making, they can better cope with everyday challenges, increase self-confidence, and improve self-esteem and autonomy. Technology can be used to assist and support individuals with autism in the development of life skills and independence [4, 18]. Among various approaches in assistive technology, physical interaction technologies, such as tangible interfaces, Wearable devices, and augmented reality displays, are widely used to support children with autism. Sitdhisanguan et al. studied the benefits of Windows, Icons, Menus and Pointing devices (WIMPs) and tangible user interfaces (TUIs) for children with autism and their results showed that TUI-based interaction achieved higher skill improvement compared with WIMP-based interaction [25]. There is growing evidence that augmented reality technology has the potential to assist autistic children. For example, 'Let's Cook' is an augmented reality game designed to develop cooking skills for children with cognitive needs [23]. 'FUTUREGYM' is a gymnasium designed for children with autism that features interactive floor projections [29]. The 'Collaborative Puzzle Game' is a tabletop interactive cardboard jigsaw activity that promotes collaboration among children with autism through collaborative movement, i.e., in order to move a puzzle piece, it must be touched and dragged simultaneously by two players [6].

Integrating technological tools within therapeutic paradigms targeting autistic children has significantly reshaped the landscape of intervention strategies [10, 21]. A growing body of research underscores the efficacy of technology-mediated interventions in enhancing the outcomes of traditional therapeutic methods. Augmentative and Alternative Communication (AAC) devices [12, 24], have fostered communication among non-verbal autistic children, thus bridging the communicative gap. Moreover, the advent of customizable mobile applications has allowed therapists to individualize learning modules based on each child's unique needs and progression pace [17, 27]. Meanwhile, wearable technologies, like smartwatches with biofeedback features, provide therapists with instantaneous insights into a child's physiological reactions [1, 7]. Leveraging this immediate data enables therapists to discern specific triggers and stress points, fostering a more anticipatory intervention approach. Torrado et al. proposed a smartwatch system that utilizes physiological signals and motion to enable expansive self-regulation strategies and infer burst patterns [30]. Carter et al. investigated the impact of computer avatars' facial features on the interactive behavior of children with autism [8]. Their results revealed that exaggerated facial movements could enhance nonverbal social behaviors, such as gaze and gestures. These platforms not only provide support for autistic children to develop their understanding of social cues and responses in a less overwhelming environment, but also offer therapists a distinct perspective to observe, evaluate, and customize interventions.

My project, "Tidd" and "MagicBLOCKS," shares similarities with the "Collaborative Puzzle Game" in its pursuit of tabletop interaction. However, it stands apart by incorporating augmented reality (AR) and offering flexibility for either solo or collaborative play. Studies such as "Let's Cook" and "FUTUREGYM" have demonstrated that augmented reality can enhance the learning experiences of children with autism, particularly when games include interactive tangible elements. Inspired by these prior works, my system design integrates AR and tangible components. Another facet of my project, "MaskME," delves into the use of wearable technology with LED displays to aid therapists at autism centers in teaching social greetings to children. My research is aimed at exploring how rich auditory and visual interactions could bolster motivation and maintain interest in children with autism. In the following section, I

will introduce the project content and completed work of the three projects included in my Research Question 2 (RQ2).

3 PROPOSED AND COMPLETED WORK

3.1 Tabletop Interactive Helps Therapists Audience Socialize Training Autistic Children

Objective: This research aimed to investigate how children with autism interacted with rich audio and visual augmented reality (AR) tabletop games.

Research design: This study approached the design of interactive tabletop gameplay for children with autism using a user-centred design methodology. Initially, we researched to understand the context, which involved in-depth interviews with therapists and caregivers of children with autism and site visits and observations of how these children participate in daily education. The formative study comprised face-to-face interviews with therapists and caregivers of children with autism and observations of the children during their daily training. The findings from this study were synthesized to develop our design guidelines. Based on these principles, we created MagicBLOCKS, an interactive tabletop augmented reality system. MagicBLOCKS supports various interaction modes, including clicking, pressing, dragging, and air gestures. The system offers 12 interactive games covering various topics and effects. MagicBLOCKS uses tangible components like building blocks, cards, colored balls, and toothbrushes for input, while digital projections provide output through colors, sounds, and animations. To evaluate the system, we conducted a four-week field study with 15 male children with autism to observe their interactions with the system. Throughout our research process, we actively involved therapists and family caregivers of children with autism, and we carefully considered their suggestions to support cognitive training and socialization exercises for children with autism within this system.

Outcomes: Our observations, interviews, video analysis, and collaborative analysis with expert therapists indicated that our MagicBLOCKS system was enjoyed by children and highly welcomed by therapists and caregivers. Our findings suggest that the MagicBLOCKS system provides children with autism the motivation and opportunities to engage with each other. The augmented tabletop game's rich audio and visual qualities were particularly rewarding and crucial in sustaining interest and motivation. Notably, themes surrounding social dynamics emerged from our observations, revealing that children with autism engaged through player performances and audience interactions, displaying cooperation and territoriality. This work has been published in a HCI journal, and the operational method of this approach can provide a design and technical foundation for future research.

3.2 Augmented Tabletop Interaction Supports Children with Autism in Practicing Daily Living Skills

Objective: This study aims to explore opportunities for children with autism to learn daily living skills using table interactive technology and storytelling.

Research design: Improving daily living skills (DLS) is one of the crucial objectives in interventions and training programs for children with Autism. Teaching DLS to children with autism in their early developmental stages can promote independence and enhance their well-being[9]. This work builds upon key findings from previous research focused on understanding the use of tabletop interaction technology to support the development of daily living skills in children with autism. Collaborating with parents and therapists, we adopted a participatory design approach to identify the specific needs of autistic person in their daily lives, enabling us to propose suitable solutions. As a result of this collaborative effort, we designed and developed Tidd, an augmented reality tabletop interactive learning system tailored for training bed-making and dressing in children with autism. The system comprises three modes: learning mode, strengthening mode, and practice mode. We employ storytelling methods and Applied Behavior Analysis (ABA) techniques to conduct repetitive exercises, enhancing the learning resilience of children with autism. Tidd offers the versatility of being used for interactive learning at home with children and to assist therapists or caregivers in intervention training. To ensure the system's integrity, we initially invited autistic children and therapists to conduct a pilot study in two autism institutions, thus improving the system's usability and stability. Based on the insights gathered from these pilot studies, we optimized the design and supplemented the child use process to ensure an enhanced user experience for the participants. Tidd highlights the immense potential of tabletop interaction in supporting children with autism in mastering daily living skills. We explore the incorporation of tangible interaction and augmented feedback to captivate the interest of children with autism and consider tabletop interactions as opportunities for interactive interventions by therapists. To validate the program's effectiveness in improving the learning ability of children with autism, we conducted a final user study involving around 20 children in a medical rehabilitation institution for children with autism and an inclusive public kindergarten. Additionally, we invited special education teachers and therapists to observe the study process, fostering comprehensive insights into the program's potential benefits. Furthermore, we discussed with therapists to explore potential opportunities and benefits of incorporating this program into their daily training course.

Future Work: This project has completed the data collection phase of the user study, and the focus will shift to data analysis in the subsequent stages. The collected data will be thoroughly analysed using qualitative research methods [13], including transcription, coding, theme identification, and presenting findings. We will group the initial codes into broader themes: 1) task completion rates and progress tracking; 2) observational data: Engagement, frustration; and 3) qualitative feedback from therapists. My collaborators

and I will independently code the data to ensure inter-rater reliability. Any discrepancies between coders will be resolved through discussion. Quantitative data from observations will be analyzed using descriptive statistics to provide a summary of participants' interaction patterns while using the tabletop system.

3.3 Wearable Mask to Promote Greetings Engagement for Children with Autism

Objective: This study aims to investigate what greeting activities autistic children would desire to participate in willingly, in the context of playful identity games and masks used as technology probes. I explored the use of animal themed masks to create opportunities for peer interaction, encouraging social greetings in children with autism.

Research design: In this research I explored the use of wearable masks to create opportunities for peer interaction, encouraging social greetings in children with autism. This research also focuses on assisting researchers at autism centres as a way to engage with society and families. MaskMe emphasizes fun, experimental facial-gaze and greeting behaviours with different playful animal energies, providing opportunities to try these behaviours in different situations and with different mindsets. We first conducted a formative study with 18 autistic children and two therapists at a rehabilitation centre to better understand how therapists help autistic children practice daily social greetings, and how games can help autistic Collaboration and interaction among children with disabilities. Based on these research findings, we identified user needs and design goals, which inspired this project's game rule design and interaction design. We designed and developed MaskMe: a wearable smart mask to support social greetings in group collaborative play for children with autism. To evaluate MaskMe's potential to support social greetings for children with autism, we conducted a four-week study with 15 autistic children aged 4 to 13 in the same autism organization. We observed the behaviour of autistic children during the game, and we also invited a therapist to stand in the same space to guide us in the study detail. We conducted post-hoc interviews with three expert therapists and requested remote commentary on key findings from video recordings of the experimental procedures by a team of expert therapists at the Autism Center.

Outcomes: Preliminary data analysis has revealed that cooperative games, when coupled with an effective reward mechanism, can foster greeting training in children with autism. The positive evaluations from therapists and caregivers also highlight the project's potential in social greeting aspects. AAdditionally, we found that MaskME has wearable smart mask features, specifically LED digital conversion and animal identification, to provide face-gaze interaction for children with autism. The mask can detect facial contacts and display instant feedback on the LED screen, fostering a sense of shared success. I will discuss how the cover's visualizations can alleviate social discomfort and materialize a shared understanding of success, as well as what it means to support greeting practices effectively. The study also includes the long-term implications of assistive technology therapists apply to autistic children, from intervention training to daily life, and how our findings can inspire design insights in the human-computer interaction community. The primary contributions of this work are 1) insights drawn from a formative study involving therapists and autistic children, which subsequently informed the design goals for game rules and culminated in the conceptualization of MaskME. 2) efforts to develop game designs and wearable masks that embody the face-to-face visual engagement behaviours of children with autism. 3) an empirical understanding of therapists' experiences teaching greetings and insights into designing and formulating future intervention strategies.

4 NEXT STEPS AND LONG-TERM GOALS

My doctoral research topic is *Interactive Technology Design for Children on the Autism Spectrum*, which primarily focuses on technology-supported interventions, early screening, and understanding of children with autism and stakeholders. At this stage, I have completed the user study for the intervention part (RQ2) and am currently focusing on data management and analysis. In the subsequent phase, I will further analyze my survey findings (possibly re-collect additional data) to answer RQ1. I will also explore the potential of assistive technology in supporting early screening and diagnosis of children with autism (RQ3). The short-term goal is to translate the knowledge I have acquired over the past few years into a functional prototype, thereby assisting therapists in their interventions and training for various skills needed by children with autism. The long-term goal is to explore interactive technology that aids people with autism from early screening to intervention and supports them throughout their life cycle.

5 PERSONAL BIOGRAPHY

I am a 3rd-year Ph.D Candidate in the Augmented Human Lab and Empathic Computing Lab at the University of Auckland. The expected completion date for my doctoral program is December 2024. I would like to thank my supervisors, Professor Suranga Nanayakkara, Professor Mark Billinghurst and Associate Professor Danielle Lottridge for their unwavering support and invaluable guidance throughout my research journey. My doctoral research is founded by the Auckland Bioengineering Institute.

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