

Co-designing Tablet Computer Applications with Sri Lankan Practitioners to Support Children with ASD

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ABSTRACT

Children with Autism Spectrum Disorder (ASD) often have impairments in social interactions with peers. Digital technology, in the form of computerized applications, can be used as a remedy for this, even though there is a paucity of such applications in low-resource regions like Sri Lanka. Therefore, we conducted co-design workshops to develop tablet applications to improve social interactions of children with ASD in Sri Lanka. 18 experienced practitioners who work closely with children with ASD in Sri Lanka participated in the workshops and co-designed two prototypes called Picture to Object Matching Application (POMA) and Word to Picture Matching Application (WPMA). We present the design process along with the insights gained from the workshops, which we believe are valuable for designing software applications for children with ASD in Sri Lanka.

Author Keywords

Autism, Children with ASD, TUI, Tablet Computers

ACM Classification Keywords

K.4.2. Social issues: Assistive technologies for persons with disabilities; H.5.2. User interfaces: User-centered design.

INTRODUCTION

Children with Autism Spectrum Disorder (ASD) often have difficulties with socializing and communicating [3]. With the advent of tablet devices such as the iPad and other portable devices, there have been technological interventions designed to improve the social and communication skills of children with ASD [6]. Due to its portability and ease of use, many developed countries (like Australia) use tablet devices in therapy and school settings to improve the social, communication, fine-motor and early literacy skills of young children with ASD [1]. Though

there many technological interventions designed with tablet applications, only a very limited number of these applications are designed to facilitate children's social interactions and collaborations with their peers. For instance, Boyd et al., 2015 designed a collaborative iPad application for children with ASD, which showed that in-game elements like partnership via assigned roles and collaboration via turn-taking gestures can improve the social interactions of children with ASD [4].

When designing software applications, researchers often use participatory design (PD) methods to involve the end-users in the design process to ensure that they understand the users' requirements. However, when designing applications for children with ASD, the PD process can be challenging as the characteristics of ASD (i.e., social and communication impairments) impact the success of the collaborative design process [12]. Acknowledging these challenges, some studies have successfully used PD with children with ASD when designing games for children with ASD [2, 10, 13]. These studies involved high-functioning older (12-15 years) children with ASD in the design process. But to embed therapeutic goals and to define the structure of the applications and roles of the players, researchers also involve practitioners who work closely with children with ASD [11].

Though there have been many technological interventions designed for children with ASD via participatory design approaches, almost all of these designs were targeted at children with ASD in developed countries, and it is not known to what extent the suggested design guidelines are applicable in low-resource countries like Sri Lanka. ASD is a global problem that affects children all around the world and there is a high demand for technologically-based interventions in countries such as Sri Lanka, given the prevalence of autism. Statistics indicate that one in 93 children in the age-group of 0-3 years may have ASD in the semi-urban areas of Sri Lanka's Colombo district [14]. Despite Sri Lanka being a low-resource country, studies show that the average age of a Sri Lankan child being diagnosed with autism is 35.8 months [15]. Thus, children with autism in Sri Lanka are often put through autism interventions at an early age [16]. However, to our knowledge, there has not been any software developed for practitioners to help meet the needs and wants of children

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with ASD in Sri Lanka. Therefore, the main objective of this study is to co-design a tool targeted at Sri Lankan practitioners to help children with ASD improve their social interactions. In this paper, we present a design approach, which gives practitioners a prominent role in the process of designing interactive applications for children with ASD. These proposed interactive applications primarily aim to improve the collaborative skills of children with ASD when they are engaging in academic activities.

WORKSHOPS WITH SRI LANKAN PRACTITIONERS

We involved practitioners in our design process in two ways: 1) they helped design the product in their role as educators for children with ASD because the intended prototypes will be used in therapy and school settings, and 2) they acted as proxy users for children with ASD to communicate the requirements of children with ASD. Thus, our approach should ensure that the design outcome will be nearly optimal before evaluating it with young children with ASD. Based on the recommendations of practitioners, we have specifically targeted children with mild-to-moderate ASD in the 3-10 years of age group for this study. The rationale for targeting this group is driven by three facts: 1) technological means are only used to treat children with mild-to-moderate ASD in Sri Lanka, 2) technological means are only recommended to treat children with ASD of or above 3 years of age in Sri Lanka, and 3) the curriculum of the autism centers picked for this study are only scoped for children with ASD who are of or below 10 years of age.

Participants

We recruited 18 practitioners (10 special education teachers, 8 therapists) who have a minimum 5 years of experience working children with ASD (and who are aged between 3 to 10 years) and have some expertise using technology with children with ASD in Sri Lanka. Each of these practitioners holds a Bachelor of Science degree and is a certified child psychologist. Practitioners who work at multiple therapy centers and schools with technology expertise were invited to participate if they possessed a minimum four years of experience in one-to-one teaching or providing therapy for children with ASD. Ethical approval for this study was obtained from our university's ethics committee, and participants' consent was obtained in writing prior to their participation.

Procedure

We conducted 6 workshop sessions with the same group of practitioners in Sinhalese (the native language of the participants). The first two sessions were explorative where practitioners brainstormed their requirements by expressing their insights and discussing them with each other. In the second two sessions, we, together with the practitioners, designed the software applications using paper prototypes. At the end of the fourth session, we gave the copies of the paper prototypes to each participant to take home for their further reflection. In the last two sessions, each participant

was given a chance to express their opinion on how to improve the prototype to suit children with ASD in Sri Lanka. Each session lasted for two hours and was conducted at Sumaga Autism Center in Colombo, Sri Lanka.

Data Collection and Analysis

We collected audio data, field notes, photographs and design artefacts (paper prototypes) in all the workshops. In the 4th and 5th workshops, practitioners handed out some sample physical toys to embed in the proposed digital application. All audio data were translated into English and analyzed using thematic data analysis [5]. The translations were verified by the first author, who is a native Sinhalese speaker, and another graduate student whose first language is also Sinhalese. To strengthen the validity of our findings, copies of reports summarizing the findings were sent to the participants for their verification. Participants were requested to comment on the accuracy of the findings as per their experience, all the participants verified the accuracy of the results.

BRAINSTORMING SESSIONS

In the first 2 sessions (brainstorming sessions), we conducted ice-breaking activities with practitioners to understand the main functionalities that are required for therapeutic applications for children with ASD in Sri Lanka. To facilitate these two sessions, we showed demonstration videos of existing applications and also gave the participants hands-on experience in using some of the more popular tablet applications (for example: "Fruit Ninja", "Toca Tea Party") that are used by children with ASD in developing countries. After practitioners had explored the applications, we asked about the limitations of existing applications and how these need to be modified to cater to the needs of Sri Lankan children with ASD. During the brainstorming sessions, practitioners emphasized that tablet applications can be a powerful tool for children with ASD as they can be used with children who have fewer well-developed motor skills. They also explained how current tablet applications could be modified to better support children with ASD in Sri Lanka, which is described below.

Support for Social Interactions and Timers

The biggest concerns most therapists (n=12) had when designing tablet applications for children with ASD is how to avoid children experiencing social isolation during the time they spend playing with the application.

"The thing about tablet applications is that they promote social isolation, and most of our children with ASD have social impairments. When we design an application, it must support social interactions" – Therapist-5.

To promote social interaction, one design suggestion made was to have multiple user interactions. By including multiple players in the same application children are forced

to interact with their peers while using the applications. Another design suggestion given by practitioners is limiting the playtime via timers and restrictions, because practitioners believed unlimited access to tablet application can lead to screen addiction among children with ASD. *“It’s important to limit the play time to a very short period when designing applications for moderate level children with ASD or else they will get addicted”* – Therapist-8.

Embedding Educational Content to Support Existing Therapies

Even though we target social interactions in this application, another key aspect all the special education teachers and educational therapist participants highlighted was embedding current educational content in the application. They further reported wanting eight key learning concepts included, namely; 1. picture matching (fruits, vegetables etc.), 2. color matching, 3. shape matching, 4. number matching, 5. number recognition, 6. letter matching, 7. word matching and 8. word to picture matching. This educational content is part of the educational therapy targeted at young children (aged 2 to 15 years) with ASD in Sri Lanka to improve their basic academic skills. *“In our therapy center, we use several guidelines when giving educational therapy to children with ASD. We start with picture matching then move to color and shape matching. Then we do number matching.... It would be great if we can embed a few of these educational concepts in this application.”* - Special Education Teacher-10.

Designing Applications with Physical Objects

Another important aspect both therapists and teachers expressed was interacting with physical objects. They believed interacting with touchscreens is not enough for healthy brain development. They further explained that in their therapy sessions most educational concepts are delivered in two forms: 1) paper-based learning where children will get a book with pictures embedding the educational materials (see Figure 1.b), and 2) play-based learning where children get to interact with physical toys that provide the same educational concepts in a playful manner to support sensory integration, brain development, and special interest (see Figure 1.a). *“We believe having paper-based learning is not enough for children with ASD for their brain development and sensory processing. We use many educational toys at therapy. Also, the toys need to be child-proof and durable (when a child bangs it on the floor or puts them in water ..”* – Therapist -1.

To support physical interactions, practitioners believed it is important to use real physical objects that children can easily relate to real-world settings. They further handed us some of the physical toys (see Figure 5.e-h) that are currently used by children with ASD in Sri Lanka to embed in our system. In addition to the familiarity of these objects, practitioners further highlighted the importance of cost

effectiveness and durability of the physical toys, due to a lack of resources in Sri Lankan therapy centers.



Figure 1. Materials used to learn shapes for children with ASD at a therapy center, (a) physical objects used to learn shapes, (b) paper materials used to learn shapes

Extendibility and Customization

Customization is another main requirement discussed by both teachers and therapists. Practitioners expressed that customization could help to facilitate different children using the same application and to make the learning more generalizable. *“We cannot always have predefined objects in the system because if we only teach what’s in the system the child will not be able to generalize. For example, if we want to teach a child what a cup is, we need to show different cups in many forms. And, whenever we show him a new cup, the child needs to understand what it is. To do that we should be able to add our own pictures to the system”* - Special Education Teacher-8.

Teachers suggested that by using the camera functionality of the tablet, they could easily personalize the learning materials for each child. They suggested that if the proposed system could have the ability to add their own photos that would allow them to personalize and customize the educational materials in a more efficient and appropriate manner. In addition to customization, extendibility is another concern reported by some practitioners (n=5). Participants mentioned that the ability to add new materials to the existing software system is also required when teaching children with ASD in Sri Lanka. *“If you can please look at the ways we can add new materials rather than the materials you upload because most of the time we change our learning materials per the needs of the child.”* – Special Education Teacher-3.

DESIGN CONSIDERATIONS AND CO-CREATING PROTOTYPES

We did not find any commercially available application that could support all the aforementioned needs in one application to support the practitioners and children with ASD in Sri Lanka. Therefore, we decided to co-design the desired application with practitioners. Since most practitioners were comfortable with sketching and drawing on paper rather than using software applications, we decided to go with paper prototypes to design the application. Some practitioners (n=3) initiated the paper prototypes by drawing on A4-sized sheets of paper to

visualize their ideas, while others actively engaged in the ideation process by giving their feedback on these drawings. The drawings were further improved via discussion and collaboration. Initial designs were drawn on 12 A4-sized sheets of paper. Two designs were finalized collectively after embedding and incorporating the positive functionalities gathered from different practitioners' opinions. The two finalized designs are: 1) Picture to Object Matching Application (POMA) design, to support young (age 3 to 7 years) children with ASD in learning to identify objects (see Figure 2a) and 2) Word to Picture Matching Application (WPMA) design (see Figure 2b), to support older (age 7 to 10 years) children with ASD learn words. After finalizing the two designs, at the end of the fourth session, one educational therapist redrew the final paper prototypes (Figure 2), to ensure all of the participants were clear about what they had agreed on.

For the user interfaces of both applications, practitioners expressed their need for a simple uncluttered interface with minimum distractions. In addition to simplicity, naturalistic images and slow music were also required and the language of the application needs to be in the Sinhalese language. For both designs, educational therapists provided sample physical toys from the therapy center that match the theme of each design. At the end of the 4th session, we took photos of the two finalized paper prototypes and sent them to all the participants via email so that they could take more time to analyze the design and give further insights in the next session. Furthermore, we redrew the same designs using MS PowerPoint©, so that practitioners could get a sense of the actual prototypes with realistic photographs.

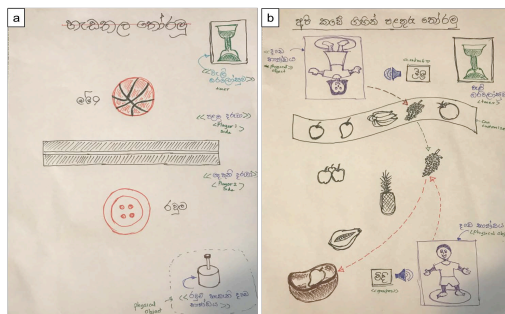


Figure 2. Design of the paper prototypes produced during the workshop (a) POMA design, (b) WPMA design.

Picture to Object Matching Application (POMA) – Design
POMA (Figure 3) is targeted at young (aged 7 years and below) children with ASD in Sri Lanka. This application was designed for two players to play in parallel at the same time via dividing the tablet screen into two sections. Since teachers requested that we embed a lot of educational content (for example, shape identification, identification of fruits), the system will consist of multiple types of activities. Based on the activity type (i.e., shapes, fruits, and vegetables), different images will be shown on both sides of the screen along with their respective name written in the

Sinhalese language. According to the displayed image, children are requested to place tangible objects on their side of the tablet screen. Unlike traditional learning methods that are currently used, a tablet-based application can cater to a wide array of images while giving immediate interactive feedback to the children. If children place incorrect objects on the screen, the system identifies that and prompts the child with cues for the correct object. For the tangible components of the application, practitioners suggested using existing pretend-play toys that are resilient and already used in the therapy centers (see Figure 5.e, f, g, h). *‘For physical toys, I think we should use plastic pretend-play toys that we use, these toys are cheap, durable and child-proof, also these toys are very relatable for our children’* – Therapist-5

Social interactions are enforced in POMA via multi-player functionality. Since both players get to play simultaneously, players sometimes get to share the same tangible objects during the play time via turn-taking. Furthermore, practitioners pointed out that through sharing the physical objects and turn-taking, the children's collaborative skills will be improved. *‘Rather than having two sets of shapes, I think we should have only one set so that children can share these objects with each other’* – Therapist-3.

To enforce time-frames, special education teachers suggested having sand-timers, with a duration of 60 seconds, in the application as they already use sand-timers in the classroom. To generalize learning concepts, practitioners requested the ability to make the images customizable so that they can add/modify new images that suit different shapes.

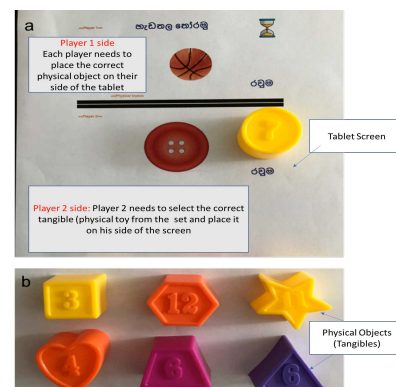


Figure 3. POMA designs that were computerized using MS PowerPoint (a) software application design (b) sample physical objects proposed for the software application.

Word to Picture Matching Application (WPMA) – Design

As most practitioners (n=15) believe POMA can only be used with younger (3 to 7 years) children with ASD, it was important to design an application that supports older children with ASD. Therefore, practitioners and researchers designed another application that could potentially support older (7 to 10 years old) children with ASD in Sri Lanka. In

this application, special education teachers requested that word to picture matching learning materials be embedded in the application. They further noted that older children with ASD require learning more advanced social interactions skills, such as collaboration, which is missing from the design of POMA. Similar to the POMA, the WPMA (see Figure 4) is also a two-player game that needs to be played in parallel, however, to play WPMA attention is required from both children simultaneously for them to succeed in the application. Player one (Child A) will be asked to pick a given fruit using a 3D human shape object while player two (Child B) gets to catch the same fruit using another 3D shape object. The fruits that need to be picked will be written in words (in the Sinhalese language) in Child-A's section. The Child A will read the letters and pick the correct fruit from the fruit belt. Once the fruit is picked by Child-A, that fruit will fall towards the Child B section of the screen where Child-B gets to catch it. When Child B catches the fruit, it will be placed in the fruit basket. After 60 seconds, children can turn-take/exchange their toys and switch their roles. After 120 seconds the game ends and children need the teacher's permission to replay it. Similar to the POMA design, timers were embedded in the WPMA design, along with customizations. Practitioners highlighted that fruits in the fruit belt need to be customized with photos of the fruits taken by them.

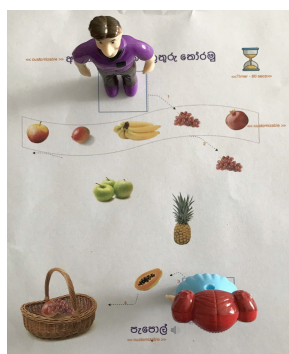


Figure 4. WPMA designs that were computerized using MS PowerPoint.

FINE-TUNING THE PAPER PROTOTYPES

During the final two sessions, practitioners discussed possible improvements to and suggestions for the customization and extendibility functionalities for the two prototypes (POMA and WPMA). Interestingly, we also noticed that practitioners came up with deeper insights and new functionalities even after the brainstorming and co-creation sessions. For example, practitioners came up with two new functionalities (i.e., a feedback mechanism and monitoring progress) during the fine-tuning sessions when we asked them to provide further feedback on the prototypes. However, those functionalities were not identified during the brainstorming sessions. This could be because we gave them the paper prototypes and computerized versions of those prototypes to take home and

therefore they had more time to think about those prototypes before providing additional insights.

Levels of Customization and Extendibility

Special education teachers were more concerned about the level of customization that is offered by the both applications. Several teachers (n=6) expressed their opinions about customizing different parts of the prototype, for example, customizing the title, customizing images shown in the prototype and customizing the time limit. One therapist explained, *"Yes we need timers, but it should not be a constant time. Because there are kids who need more time. The time of play needs to change per the child."* - Therapist – 2. In addition to customization, extendibility was again discussed during the final sessions. Teachers explained the need to have many different educational materials, not only shape identification, embedded in the POMA. For example, educational content such as fruit and vegetable names, animal names (see Figure 5), need to be added to the application. Similar to POMA, WPMA also requires support for extendibility, so that other educational content such as festive food, fruits, or vehicle names can be embedded in the application to improve the academic skills of children with ASD.



Figure 5. Types of learning materials that need to be included for the POMA. a, b, c, and d represent paper-based learning materials that need to be included in the POMA. e, f, g, and h represent proposed tangible pretend-play toys for the POMA.

Monitoring Progress

Monitoring the progress of the child via the application is another idea that emerged from the special education teachers. Teachers explained the importance of monitoring the child's progress to add or modify the educational contents of the application to understand the children's academic success. *"It would be good to keep track of the score and monitor the child so we can give what the child needs via this application"* – Special Education Teacher-6.

Multi-Sensory Feedback Mechanism

The first concern most practitioners had regarding the two prototypes was the feedback mechanism. They further highlighted the importance of having a sensory reinforcement mechanism for children with ASD and explained when feedback is required for children with ASD. *"At the end of the game, we can have something like*

‘Good Job’ with animated fireworks to praise the child – Educational Therapist-1. Most practitioners (n=10) claimed that text-based feedback such as “Good Job” would be more appropriate to give at the end of the game, while immediate feedback (i.e. sound-based feedback) is necessary for every correct input from the child.

DISCUSSION

One of the key concerns therapists had when designing both applications was embedding social interactions in the software applications while also embedding academic skills. This aligns with recent studies in the United States that explore what individuals with ASD require from technology. The results of this study show that two of the major things that users want from this technology is social and academic skills development [17]. Additionally, most Sri Lankan therapists believe that though interactive tablet applications can benefit children with ASD, tablet applications can also promote social isolation for children with ASD as most such applications have only child to tablet interactions. To mitigate this concern, practitioners suggested designing applications that enable multiple user interactions simultaneously via collaborative activities and role changing. Through this approach, children are forced to connect with their peers when using the tablet applications. In prior research, there are a few tablet applications that show assigning roles and collaborating via turn-taking can improve social interactions in children with ASD. However, these applications do not embed educational contents inside their game designs, nor do they involve any physical components [4]. However, practitioners in Sri Lanka believe that embedding day-to-day physical toys in digital applications can also help children learn collaboration via sharing physical objects with their peers.

In addition to learning collaboration, practitioners also highlighted that using familiarized physical objects can especially benefit children with ASD to develop sensory integration deficits and to support their special interests, which are key traits of ASD [18]. Prior research has found that Tangible User Interfaces (TUIs) improve the cooperative skills of children with ASD while reducing the duration and frequency of their solitary activities [9]. In developing countries, there has been some research targeting social interactions via multiple-users with TUIs. These applications [22] are designed to be on tabletop devices, which enable social interactions via turn-taking of tangible objects and multi-user interaction via shared surfaces. Though the results of these tabletop applications are promising, they might not be affordable for low-income countries like Sri Lanka. Furthermore, most smart toys that are designed for children with ASD in high-income countries are not cost effective and not relatable for children with ASD in Sri Lanka [8]. Sri Lankan practitioners require more cost-effective, durable and realistic day-to-day tangible objects (i.e., plastic pretend-play kitchen sets), where Sri Lankan children can easily

relate to them in their familiarized settings, something which has not been addressed in other research. By contrast, our proposed designs are suitable for low-income countries to improve social interaction while supporting the multi-sensory integrations of children with ASD.

Customizing the application content (its images, time, or sounds) is another area that got highlighted during the design process as most children with ASD have unique special interests [21]. This concern has been discussed in previous autism research conducted in developed countries, for instance, social skill applications such as ‘Our Story’ [6] support audio and visual customization. However, in addition to customization, Sri Lankan practitioners require extensibility support, such as adding new educational content other than the predefined ones.

In addition to customization, practitioners highlighted the need for sensory reinforcement and feedback as children with ASD enjoy specific visual and audio stimuli. This is in line with the design guideline that children need to be rewarded with a sensory experience when they give the correct response [20]. Additionally, practitioners also highlighted that applications should not make any sounds or provide any visuals when the child answers incorrectly. This finding also relates to the design guidelines from another developing country (Thailand), which illustrates that incorrect response feedback should be kept to a minimum or avoided in software applications designed for children with ASD [19].

Embedding timers into the application to bring structure and to avoid addiction is another functionality that was requested by special education teachers in Sri Lanka. This accords with prior research that has shown timers can be used as a visual cue for children with ASD to limit the time allotted for an activity [7]. While therapists in developed countries use digital timers in facilitating activity transition for children with ASD [1], most Sri Lankan practitioners requested that we embed digitalized sand-timers in the tablet applications. Practitioners also highlighted timers are not enough in themselves for some children with ASD, as they tend to keep using the application even after the allocated time, and so require more restrictions. Therefore, we propose to have authorization (via passcodes) inbuilt in replay buttons, to restrict unlimited access to the application.

CONCLUSION AND FUTURE WORK

In this paper, we presented the design of two interactive applications (POMA and WPMA) that target learning academic skills via collaborative activities for children aged 3 to 10 years with ASD in Sri Lanka. In our future work, we aim to build the interactive versions of the paper prototypes using the design guidelines provided in this paper and then evaluate them with practitioners and children with ASD in Sri Lanka.

SELECTION AND PARTICIPATION OF CHILDREN

No children participated in this work.

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