Evaluation of Tablet Apps to Encourage Social Interaction in Children with Autism Spectrum Disorders

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ABSTRACT
The increasing rates of diagnosis for Autism Spectrum Disorders (ASDs) have brought unprecedented attention to these conditions. Interventions during childhood can increase the likelihood of independent living later in life, but most adults with ASDs who benefited from early intervention do not live independently. There is a need for novel therapies and interventions that can help children with ASDs develop the social skills necessary to live independently. Since the launch of the iPad, there has been a great deal of excitement in the autism community about multitouch tablets and their possible use in interventions. There are hundreds of apps listed as possibly helping children with ASDs, yet there is little empirical evidence that any of them have positive effects. In this paper we present a study on the use of a set of apps from Open Autism Software at an afterschool program for children with ASDs. The apps are designed to naturally encourage positive social interactions through creative, expressive, and collaborative activities. The study compared activities conducted with the apps to similar activities conducted without the apps. We video recorded the activities, and coded children's behavior. We found that during the study children spoke more sentences, had more verbal interactions, and were more physically engaged with the activities when using the apps. We also found that children made more supportive comments during activities conducted with two of the apps. The results suggest the approach to using apps evaluated in this paper can increase positive social interactions in children with ASDs.

Author Keywords
Autism; app; tablet; social skills.

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INTRODUCTION
Multitouch tablets, including iPads, have made computing more accessible for a wide variety of populations. The simplicity of touch interactions and the portability of these devices have lowered the barriers for interacting with computers. A quick search for online videos yields older adults enjoying card games, toddlers playing games, and even frogs frustrated at not being able to eat ants on the screen.

Multitouch tablets have also brought hope to people with autism spectrum disorders (ASDs) and their families. ASDs are characterized by challenges in communication, social interaction, and symbolic or imaginative play [2]. An increase in the rate of diagnosis, with 1 in 88 children in the United States diagnosed with ASDs, has brought greater visibility and attention to ASDs [6].

The preference of many children with ASDs for touchscreens has long been documented [47, 51, 55]. In fact, a very expensive yet popular device for augmentative and assistive communication, the DynaVox, served many people with ASDs long before tablets became widely available [13]. The arrival of iPads has brought with it a veritable downpour of excitement about their use primarily by children with ASDs. For example, a recent feature in *60 Minutes*, a popular television news program in the United States highlighted anecdotes of children with ASDs using iPads [5]. The enthusiasm has also reached non-profit organizations dedicated to ASDs research, with *Autism Speaks,* one of the most important ones in the United States, recently starting an initiative called *Hacking Autism* to develop tablet apps [24]. This excitement has produced hundreds of apps that purportedly help children with ASDs, making it difficult for caregivers to identify useful apps [1] [24].

This difficulty is only made worse by the lack of empirical data supporting the use of specific approaches to the design or use of multitouch tablet apps for children with ASDs. Beyond making interaction simpler and more accessible, what actual activities with multitouch tablets can help children with ASDs improve in areas where they face challenges?

For the research presented in this paper, we used a set of free, open source, multitouch tablet apps from Open Autism Software [31]. These apps and the activities we conducted with them aim to help children with ASDs associate social interaction with positive feelings by making it happen naturally through creative, expressive and collaborative activities. In this paper, we focus on an evaluation of the impact of these activities on children over several months in an afterschool program. When comparing social behaviors with and without app-based activities, we found using the apps was associated with increased verbal communication, physical interaction, and supportive comments. In doing so, we contribute one of the first bits of empirical evidence supporting a specific approach toward the design and use of multitouch tablet apps for children with ASDs.

RELATED RESEARCH

A Deeper Look at ASDs

Depictions of people with ASDs in popular media can lead to stereotypical views on the characteristics of this population. In particular, there can be a sense that people with ASDs are similar to each other. The reality is that there is significant variability within this population [6]. Some people with ASDs do not speak, while others do not know when to stop talking. Some cannot make eye contact, while others will stare at people in socially inappropriate ways. In fact, leading scientists specializing in ASDs are reaching the conclusion that ASDs are not one condition, but many [9]. In addition, context can significantly affect the behavior of children with ASDs, leading to within-child variability [37]. Therefore, variability is an important factor to take into account when designing technologies for this population.

The common thread running through the spectrum and the main barrier preventing most high-functioning children with ASDs from growing up to be independent adults is challenges with social skills. In our own work with children with ASDs we have met many children who are quite talented, yet may not be able to fully share those talents with the rest of us due to their limited social skills. Early diagnosis and intervention are critical for improving these skills [26]. But even for those who benefited from early intervention, the percentage of adults with ASDs who can live independently remains low [3, 14, 32]. Therefore, while tools for early diagnosis are crucial, there is also a need to go beyond them and develop novel interventions.

The intervention for which there is the most evidence of positive effects is applied behavior analysis, which uses a behaviorist approach to teach skills in areas such as speech and motor skills [15]. These interventions are highly structured and use clear instructions, repetition, practice, and reinforcement. Naturalistic methods are also commonly used, taking advantage of children's interests to teach skills. For example, picture dictionaries can help children communicate their needs if they are not able to speak [52]. These interventions tend to be very costly, with estimates for intensive therapy in the United States ranging from 40 to 60 thousand dollars a year per child. This is in addition to medical costs that are about six times those of children without ASDs [6]. In addition, there are few free resources available. Therefore, any role technologies can play in reducing costs can make a difference, especially for families with limited financial resources.

Due to the complexity of needs for this population, there are usually several stakeholders that will be affected by interventions. Besides the people with ASDs themselves, stakeholders include parents, other family members, teachers, clinicians, therapists, caretakers, classmates, and so forth. From an interaction design perspective, having so many stakeholders increases the complexity of the design process, especially for technologies that may be used in multiple contexts.

Computer-Based Interventions

The most similar computer-based interventions to the ones evaluated in this paper are those that use multitouch screens. The pioneers in this approach were Piper et al. [44] who designed a four-player tabletop application. They found it to be effective in engaging children with ASDs, even though it required group work. Hendrix et al. worked with shy children, instead of children with ASDs, but followed a similar tabletop approach successfully, in this case giving shy children special roles to positively engage them with peers [29]. A collaboration between Israeli and Italian institutions yielded several activities on multitouch tables, some story-based, with examples of enforced collaboration used to encourage collaborative behaviors among children with ASDs [21, 23, 53]. These are all examples of applications that make use of computers to encourage face-to-face interactions for children with ASDs. The apps used in the research described in this paper have a similar goal, although the activities are less structured, and use tablets instead of tabletops. It also is unclear whether the benefits obtained with tabletops can be obtained with tablets, given differences in size, orientation, and mobility.

Tangible devices are another way to engage children with ASDs in face-to-face interactions. Examples include the work of Farr et al. with Topobo and LEGO toys [18], experiences with robots [19, 46], and toys with sensors and actuators [12].

Mobile devices are also increasingly used to support people with ASDs in their social interactions. A group at MIT implemented emotion-recognition algorithms on a mobile device to help people with ASDs who have difficulty recognizing emotions in face-to-face situations [38]. Escobedo et al.'s MOSOCO, based on previous work by Tentori and Hayes [50], provided children with instructions on how to interact with peers in a playground [16]. In addition, there are many software apps for both mobile phones and tablets that enable their users to communicate by selecting picture symbols that are then translated into speech for face-to-face communication (e.g. [47]). These follow the example of the DynaVox we mentioned previously, but are significantly more affordable [13].

Virtual characters can enable children to practice face-to-face communication, or to even communicate with others through a virtual character. Examples of this line of research include the work of Tartaro and Cassell [49] and the ECHOES project in the United Kingdom [20] [45].

Researchers have also developed many applications targeting traditional desktop and laptop computers, with the aim of improving a variety of skills related to communication. These include building vocabulary, vocalizing words, reading human faces, and learning about appropriate forms of communication (e.g., [4, 7, 17, 25, 39, 55]).

Other approaches aim to support children with autism, but are not specifically geared at improving face-to-face interactions. These include the computer-based implementation of visual-supports, schedules, and other common tools used in schools [28, 30]. Others are geared at developing motor skills, relaxation, and learning about cause and effect [34, 43], and there has also been a significant amount of research on tracking children's behavior (e.g., [1, 27, 35, 40, 54]).

DESCRIPTION OF APPS USED IN THIS STUDY

Overall Approach

The approach of the apps evaluated in the study presented in this paper is significantly different from that of the research reviewed above, and from the commercial apps developed for children with ASDs. The Open Autism Software suite aims to help children enhance their social skills by using tablet apps to entice children to engage in positive face-to-face interactions [42]. The idea is to help children practice social skills in activities they enjoy, where face-to-face interactions are desirable to them. This in turn can lead to children with ASDs associating positive feelings with face-to-face interactions. As the name of the suite implies, the apps are free and open source, and are written in Python, enabling them to run on a variety of platforms including Tablet PCs, Linux, MacOS, and Windows (not iOS).

The suite consists of a set of simple, flexible apps that can be used in a variety of activities involving creative, collaborative, and expressive endeavors. This focus is quite different from the prevailing behaviorist approaches. The intention is not to replace these existing approaches, but to complement them.

To provide an individualized experience, session facilitators can select a subset of apps and activities that best suit the participating children given their current needs and context. This contrasts with more typical approaches to customization that usually involve changing settings within a particular technology.

The apps have very simple user interfaces with little or no use of words to better appeal to a population that can often better process information visually than verbally [11], and can easily be distracted by irrelevant visual stimuli [41]. There are also no right or wrong ways of doing things in the apps, which in this case is intended to enable the children to explore the apps, feel free to express themselves, and reduce anxiety [22].

Description of Apps and Activities

In the research described in this paper we used four Open Autism Software apps. These are described in the Open Autism Software website, which includes videos [42], and in an article that included case studies [31]. We used the apps on a Dell XT2 Tablet running Windows 7. Below, we provide a brief description of the apps and the activities we conducted with them.

The first app, Drawing, allows children to express their creative ideas, interests and emotions through art. It provides basic drawing through the stylus, as well as panning and zooming using the pinch gesture [36] (pan with one finger, zoom and rotate with two fingers). It also includes a simple palette to change colors. This app is mainly used for collaborative storytelling for two or more participants. In the collaborative storytelling activities we asked children to take turns adding the next visual scene in a story. These activities promote creativity, fine motor skills, sharing, and collaboration.

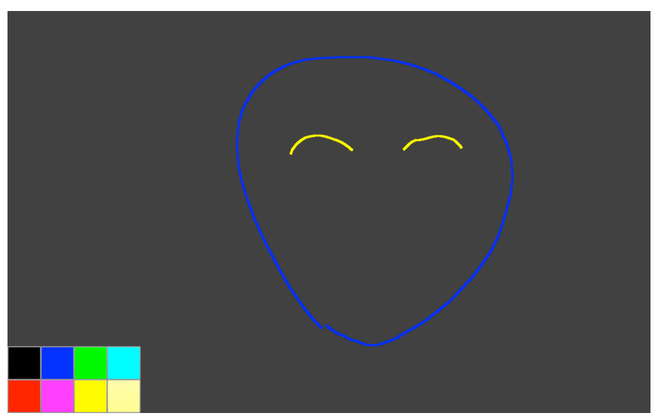

Figure 1. Drawing application showing color palette.

The next app is called Music. This app presents the user with a screen full of gray blocks. Touching a block turns it orange and produces a note. Touching it again removes the note. Using this method, users can create a short melody that the application continually loops through. Each column is played in turn, with the current column in green. Notes higher in each column representing higher pitched notes, and vice versa. For collaborative composition activities, we asked children to take turns adding a few notes until they were satisfied with the music. This activity helped children practice fine motor skills and turn taking.

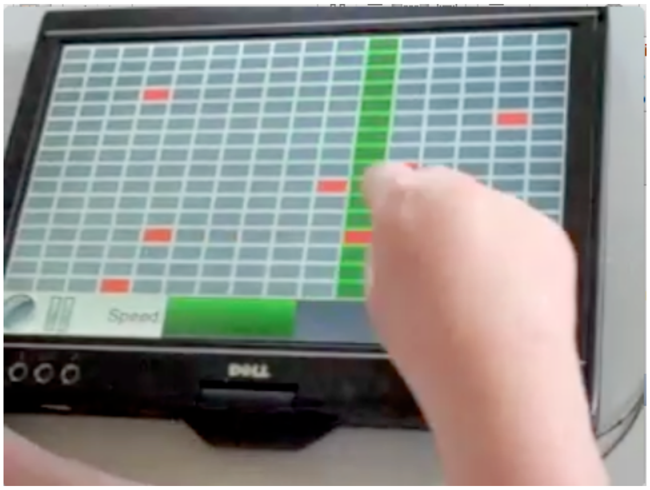

Figure 2. A child using the Music app.

The third app, called Untangle, presents a visual puzzle. It appears as small circles, each connected to two other circles by straight lines. To solve the puzzle, users have to move the circles so that no lines overlap. When played collaboratively, the goal of the game is to encourage participants to cooperate and coordinate their actions. It also supports fine motor skills and sharing.

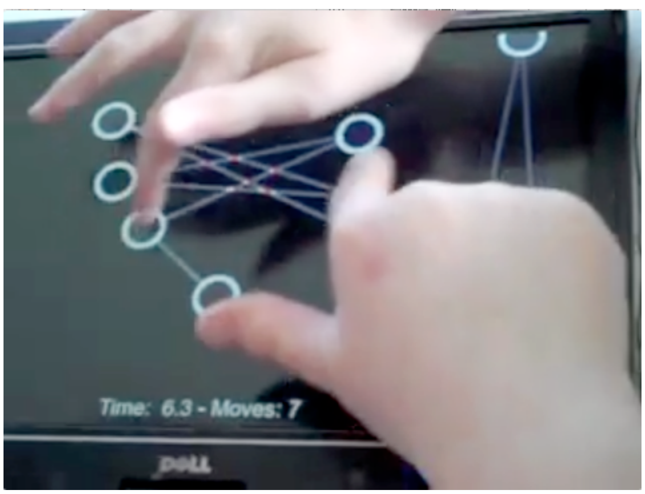

Figure 3. Two children using the Untangle app.

The last app is called Photogoo. In this app, users select an image within the application and then manipulate it by either distorting it with their fingers, or by drawing over it with the stylus. The application can be used for emotion modeling, where we ask children to change a face so that it looks like it displays a particular emotion. Many children also find this app quite amusing, especially when deforming the faces of adults they know. In this manner, it can be used as a reward, or to enhance a child's mood.

Figure 4. Photogoo with a modified Mona Lisa.

RESEARCH QUESTIONS

We wanted to learn whether the activities conducted with the Open Autism Software apps could lead to children diagnosed with ASDs being engaged in the activities themselves and socially with each other. To provide a fair comparison, we decided to compare them to non-computer activities that closely resembled the app-based activities.

METHOD

Participants

The participants were eight children, five boys and three girls. They were 10 to 14 years old (average age 12.5). They all attended an afterschool program for children with ASDs, intended for children on the higher end of the spectrum. The program used two rooms in a recreational center a few blocks away from our university.

Before we began our study, but after the children had a few weeks of daily activities with staff from the afterschool program, we asked the head of the staff to fill out the Super Skills Profile of Social Difficulty, which is used as part of the Super Skills program for children with ASDs [8]. The questionnaire rates children in four different skill areas through several questions under each area. These skill areas are: fundamental skills, social initiation skills, social response skills, and getting along with others. The scale goes from 0 to 6, with 0 being "very difficult" and 6 being "very easy". Figure 5 shows a summary of the scores for participating children and also illustrates the diversity of the population, even among a group of children who were grouped because of similar needs and abilities.

Materials

To have a fair comparison with the Open Autism Software apps, we developed equivalent activities that did not involve computers. As a counterpart to the Drawing app, we brought large sheets of paper (25 by 30 inches) together with markers. Using these materials, we facilitated collaborative storytelling activities the same way we did for the Drawing app. As a counterpart to the Music authoring app, we brought a music keyboard that children could take turns playing. As counterparts to Photogoo and Untangle, we observed the children conduct their regular activities at the program, which included playing board games, working on art projects, and practicing social skills.

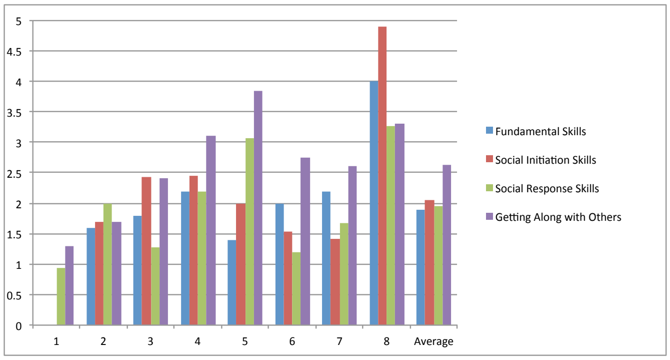

Figure 5. Skills for the eight children participating in the study according to the Super Skills Profile of Social Difficulty. The x-axis shows sets of bars for each child (and one for the aveage). The y-axis show the ratings on a 0 to 6 scale (the higher, the better the skills).

Procedures

We conducted research activities in the afterschool program on Monday afternoons starting in September of 2011 through April of 2012. We conducted activities with all the children who were present every time we went. It was common for a couple of children to be absent. The staff at the afterschool program would send two children at a time to work with two researchers, one facilitating the session, and the other video-recording it. In addition, a member of the afterschool staff was always present during the research sessions.

The role of session facilitators was the same for all conditions and involved introducing an activity and helping it move along by, for example, prompting children to end their turn. For the storytelling activities (with app or large sheet of paper), the instructions were exactly the same, asking children to get started on a story with a "once upon a time there was a…", asking them to draw first and tell the story later, and take turns adding elements to the story. We followed the same pattern for other activities.

The sessions were conducted in a room adjacent to where the regular afterschool program activities occurred. Each session with a pair of children was usually 10 to 15 minutes long.

Design

This was a within-subjects study. The independent variable was the type of media used (apps vs. non-computer). We began the study with children using the apps, with observations from 14 sessions (we usually hosted three or four sessions during each visit). We then proceeded to facilitate the non-computer activities, with observations from 40 sessions. After this, we returned to app-based activities for another 25 sessions.

This design provided us with the ability to observe changes in behavior over time, and gave us a chance to compare the values of the independent variable with less concern about learning or changes in behavior due to other factors.

We coded the videos for events related to social skills and engagement in the activities, yielding the dependent variables for the study. We describe the coding process in the next section.

RESULTS

Below, we first describe how we coded the videos. We then discuss results by dependent variable. For statistical analyses, we used SPSS 19. All the variables we coded were numeric. We tested whether they had a normal distribution using Kolmogorov-Smirnov's test. If they had a normal distribution, we compared activities with and without apps using a paired t-test, or a repeated measures ANOVA if comparing the three sets of sessions. For data that was not normally distributed we used Wilcoxon's signed ranks test when comparing two values of a variable, and Friedman's test for more values. The statistical analyses used average values of each variable per child for each set of the three sets of sessions.

Coding of Video Recordings

The videos of the recorded sessions focused on the children, as opposed to filming what they were doing with the apps or other materials. Therefore, we were able to capture their facial expressions and what they did with their bodies during the sessions.

Three researchers who had not previously participated in the project coded and processed the video recordings. One researcher performed the coding of the videos. Two other researchers transcribed all the sessions verbatim.

We decided to code events that would reflect social engagement as well as engagement with the activities. The coding researcher did the coding by watching video to avoid mistakes due to the use of sarcasm by some children. Below are the types of events we coded, together with a brief description of each.

Verbal interactions. We coded for the number of verbal exchanges by children in a session to separate it from how much they spoke since a few of the children could go into long monologues. We counted a new verbal interaction when the child speaking would change, or whenever a child would speak after an adult spoke.

Supportive comments. These are cases where a child verbally expressed support or encouragement toward another child. We also included cases when they provided helpful suggestions to other children. Examples: "I think it looks awesome!"; "Perhaps you should move that…you might want to move that green circle over here"

Discouraging comments. These are cases where a child verbally expressed displeasure toward another child or verbally criticized them. Examples: "Stop saying shy! What is wrong with you?" (said during a session where one student presented an emotion and the other had to guess).

Physical interactions. We primarily looked for turn-taking, counting a new interaction with each turn taken, but also counted it as an interaction if a child joined into the other child's turn (e.g., playing a keyboard together, or adding notes to the Music app together). We decided to code this to provide a sense of the children's engagement in an activity.

Atypical behavior. We coded for non-verbal behaviors that would be unusual in typically developing children. These included rocking, jumping, and making noises during sessions.

Social missteps. These included inappropriate tone of voice, staring or avoiding eye contact, invading personal space, and interrupting or breaking a social interaction.

Time off-task. We coded the beginning and end of episodes where children would do something other than participate in the activity.

We also transcribed all the sessions verbatim. We used these transcripts to measure the number of sentences spoken by children per session.

Since sessions were of different lengths, we normalized all the measures above to occurrences per minute (e.g., sentences per minute, supportive comments per minute).

Number of Sentences

The number of sentences per child per minute was normally distributed. A paired t-test found a statistically significant difference in the number of sentences per child per minute between sessions with and without apps ($p=.005$). Children spoke more sentences per minute when using the apps. Comparing the three sets of sessions through a repeated measures ANOVA did not yield statistically significant differences. See the differences between sessions with and without apps in Figure 6.

Verbal Interactions

There was a statistically significant difference in the number of verbal interactions per minute between activities with and without apps ($p=.001$), based on a paired t-test. However, this did not extend to a statistically significant difference when comparing the three periods of activities. There were more verbal interactions per minute when children used apps. Figure 7 shows the change over time with a clear dip in the number of verbal interactions per minute when no apps were used. Figure 8 gives a sense for the variability between children showing changes with one line per child.

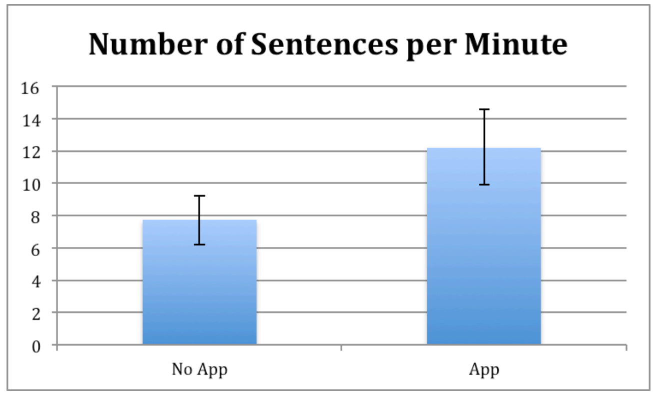

Figure 6. Number of sentences per child per minute comparing sessions with and without the use of apps. Error bars are two standard errors long.

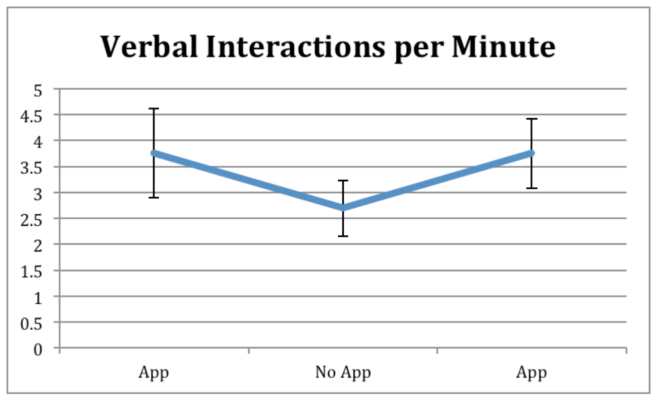

Figure 7. Verbal interactions per minute. Error bars are two standard errors long.

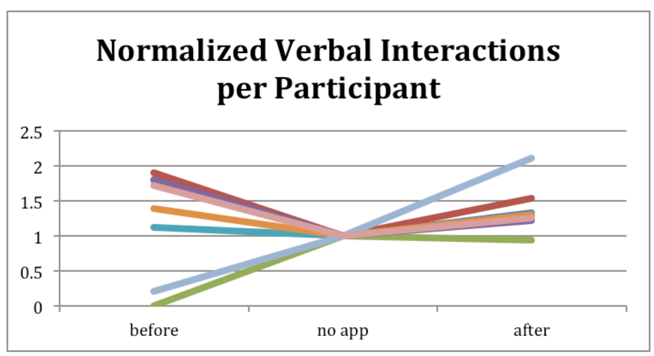

Figure 8. Verbal interactions per participant normalized by the average verbal interactions per minute for the set of sessions without apps.

Supportive Comments

There was no statistically significant difference between sessions with and without apps in terms of supportive comments. However, a closer look at the data revealed differences if we broke down numbers by activity (e.g., Drawing, Music, Photogoo, Keyboard). Further investigation revealed that there were many more supportive comments with the Music and Untangle apps than with any other activity (see Figure 9).

There were statistically significant differences between the activities with the two apps that promoted supportive comments, those with the apps that did not, and those with no apps. Friedman's test yielded p=.011.

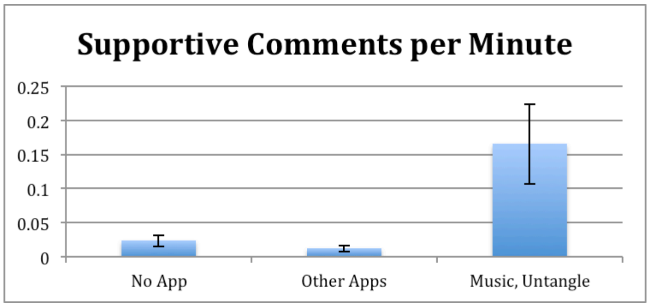

Figure 9. Supportive comments per minute by type of activity. Error bars are two standard errors long.

Discouraging Comments

There were no statistically significant differences in terms of discouraging comments.

Physical Interactions

There were statistically significant differences when comparing physical interactions per minute in the three sets of activities through a repeated measures ANOVA, adjusting for lack of sphericity through Geenhouse-Geisser ($F(1.1, 6.6)=7.528$, $p<.05$, power=.66). Figure 10 shows the changes in the number of physical interactions, with a clear dip when children switched to no apps, and with numbers not quite picking up to the original level when children returned to using apps.

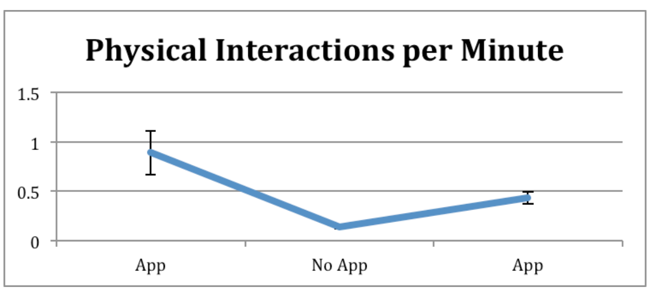

Figure 10. Physical interactions per minute. The error bars are two standard errors long.

Other Dependent Variables

We did not find any statistically significant differences between app and non-app activities for atypical behavior, social missteps, or time off-task.

DISCUSSION

The results provide some of the first empirical evidence of tablet apps helping children with ASDs engage in positive social behaviors. In particular, the greater rate of verbal interactions suggests that the children in the study engaged in more exchanges with others during these activities. Likewise, the two apps that led to more supportive comments may provide useful ideas for additional activities that may enable children with ASDs to practice more advanced social skills.

Beyond the impact on children with ASDs, this study is also a rare example of tablet apps leading to higher quality face-to-face interactions.

Why Did It Work?

The app activities that were part of the study took advantage of children with ASDs' interest in computers and technology to have them engage in social activities. In the research we have conducted with dozens of children with ASDs, the most consistent interest we have found is in some variation of computers. This interest is understandable given the difficulty these children have with social interactions. In our conversations with participants, we have learned that one of their main sources of anxiety comes form uncertainty or unexpected events. Interacting with computers is much more predictable and controllable than interacting with people. We believe that the social interactions in the app activities were easier and more comfortable for participants because they happened in the context of an enjoyable activity with a computer. This made the children more confident, less anxious, and led to increased engagement.

In terms of the two app activities that generated more supportive comments, we believe they did so for somewhat different reasons. In the Music app activity, children liked the music they made together, and would often comment on how they liked what another child had done. The advantage the app provided is that it did not require any expertise to create likable music. The Untangle app activity timed children on how quickly they would complete a puzzle, giving them an incentive to complete it faster, appreciate help from others, offer help, and provide encouragement.

Limitations

The number of participants was low compared to most HCI research studies, but similar to other studies involving special needs populations. The length of the study and the need for researchers to engage directly with participants during each session limited the number of participants with whom we could work. Adding more participants would have likely meant adding additional sites to the study, which would bring with it additional factors due to different contexts.

There are also limitations due to the variability between children with ASDs. Because of this variability, the small number of children in the study, and the lack of additional randomization, the results from statistical tests presented in this study should be taken with great caution. The descriptive statistics shared through charts though, provide strong evidence supporting our overall conclusions. However, children with ASDs, but with different needs and abilities from those who participated in the study may not benefit from using the apps. Children with ASDs also vary their behavior significantly based on context, and conducting similar activities in different contexts could yield different results.

The study setup had some limitations. There were not an equal number of sessions with apps before and after the sessions without apps. However, the statistical methods we used adjusted for these differences. There was also only coder, which could have compromised reliability.

Parents should be aware that the fact that we obtained positive results favoring tablet apps in this study does not mean that iPads or other tablet apps will benefit children with ASDs. However, we expect that similar approaches to those used in this study, where apps are used to encourage positive face-to-face social interactions through creative and collaborative activities are likely to yield positive results for children with similar backgrounds to those in the study.

Future Work

An obvious follow up to this study would be a larger one with more sites. It would also be useful to increase the frequency of these activities (e.g., hosting them every day), so that the chances that they may influence children's behavior in other activities would increase. It would also be useful to develop similar activities with lower functioning children with ASDs in mind, to help them develop more basic social skills.

We have also noticed in some of our sessions that some of the children seemed to improve their mood during the app-based activities. This could lead to an additional research study.

In addition, we think it would be interesting to analyze the types of stories, music, and other creations that children with ASDs put together during these activities.

CONCLUSION

In this paper we presented a study evaluating the use of tablet apps for encouraging social interaction in children with ASDs. In the study, children with ASDs spoke more sentences, engaged in more verbal exchanges, and were more physically engaged with the activities when involved in app-based activities than when conducting similar activities that did not involve tablet apps. In addition, two of the activities pursued with apps led to a greater number of supportive comments when compared to other activities. These results suggest the approach to tablet activities presented in this paper may have a positive effect in children with ASDs' social interactions.

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