Supporting Shy Preschool Children in Joining Social Play

Flannery Hope Currin
Computer Science, The University of Iowa, Iowa City, Iowa, United States
flannery-currin@uiowa.edu

Kyle Diederich
Computer Science, St. Norbert College, De Pere, Wisconsin, United States
kyle.diederich@snc.edu

Kaitlyn Blasi
Informatics, The University of Iowa, Iowa City, Iowa, United States
kaitlyn-blasi@uiowa.edu

Allyson Dale Schmidt
Informatics, The University of Iowa, Iowa City, Iowa, United States
allyson-schmidt@uiowa.edu

Holly David
Computer Science, The University of Iowa, Iowa City, Iowa, United States
holly-david@uiowa.edu

Kerry Peterman
Informatics, The University of Iowa, Iowa City, Iowa, United States
kerry-peterman@uiowa.edu

Juan Pablo Hourcade
Computer Science, The University of Iowa, Iowa City, Iowa, United States
juanpablo-hourcade@uiowa.edu

ABSTRACT

Executive functions (EF), a set of cognitive processes necessary for goal-oriented behavior, are critical for children's school outcomes and often lacking when children arrive in elementary school. One of the most promising interventions to address this gap is *Tools of the Mind* (*ToM*), a Vygotskyan approach to early childhood education with a strong emphasis on sociodramatic play. One challenge in implementing this kind of play is supporting children in joining play with their peers. In this paper we present a content analysis of an eight-week evaluation comparing implementing *ToM*-style play with and without technology supports. We found that one specific aspect of the technology supports, a voice agent, played a crucial role in integrating shy children into sociodramatic play.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); • **Social and professional topics** → User characteristics; Age; Children.

KEYWORDS

Children, preschool, executive functions, play

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1 INTRODUCTION

During the past decade there has been a dramatic increase in children's use of computing devices, in particular mobile devices, such as smartphones and tablets. In the United States, for example, children age 0-8 went from 5 daily minutes of screen time on these mobile devices in 2011 to 48 minutes by 2017 [81]. Most of this time is spent watching videos or playing games [81]. These trends have brought concerns about children's social isolation [84], lack of engagement in creative activities [42], and disconnection from the physical environment through excessive sedentary activities [30]. The child-computer interaction community has long advocated for balancing these kinds of experiences with technologies that do the opposite of what these concerns suggest: supporting communication, creativity, and connections with the physical environment [47]. Well-known examples include embodied game-like technologies for learning (e.g., [4]), research on technology-augmented outdoor play (e.g., [5]), and indoor physical play (e.g., [55]).

These examples all involve a form of play which leads to social, creative, physical activities. In this paper, we are concerned with a particular kind of play for which there is a significant amount of empirical evidence of benefits to preschool children: sociodramatic play in the style of the *Tools of the Mind* (*ToM*) curriculum [13]. *ToM* is focused on helping children develop executive functions (EF), a collection of cognitive processes (e.g., attentional control, cognitive flexibility, emotion regulation) that are necessary for goal-oriented behavior [3]. These skills are critical for children's school success [11, 17, 78] and better outcomes throughout life [33, 58]. Ages 3-5 are a critical time for the development of these skills [17, 23, 34], yet many children fail to acquire them [66, 79], risking falling behind in school [9, 25]. There is evidence that children who regularly participate in *ToM*-style play score better on tests of EF and later perform better in school than those who do not [10, 11, 26, 28, 59]. *ToM* is a Vygotskian approach to play. While there are many perspectives on play, we focus in this work on the Vygotskian approach because of the evidence supporting the developmental benefits of this type of play for 3-5-year-old children described in

Section 2. There are opportunities for interactive technologies to support these activities.

Pantoja et al. developed technology supports to lower barriers to *ToM*-style play by working with two groups of 3-4-year-old children over 39 design sessions [61, 62]. These supports, called *StoryCarnival*, include interactive stories to motivate play, a play-planning tool, and voice agents controlled by adult facilitators to keep children engaged in play. In this paper, we present an eight-week evaluation with a group of five 3-year-old children and a group of twelve 4-5-year-old children comparing their behavior during *ToM*-style play with and without the support of *StoryCarnival*. We coded for specific behaviors characteristic of *ToM*-style play (e.g., symbolic usage of props) to assess whether the system effectively supports *ToM*-style play and also employed an open coding scheme to identify whether there were other areas in which the system was especially useful or could use improvement. We found in sessions in which we used technology supports, the voice agents helped integrate shy children who otherwise had difficulty joining sociodramatic play. In this work, we defined shy children as those who were less verbally participative in play than their peers and displayed reticent behaviors as described by Coplan during play sessions with their peers (e.g., watching other children play without initiating or joining in peer interactions) [24].

In the remainder of this paper, we first motivate the research by presenting the impact of *ToM*-style play on EF; we then describe *StoryCarnival*, related work, our methods, and our results; finally, we discuss the implications of our key findings.

2 EVIDENCE OF BENEFITS OF THE TOOLS OF THE MIND APPROACH

One of the most successful approaches to develop EF for children under the age of five is *Tools of the Mind* (*ToM*)-style sociodramatic play [27]. *ToM*-style play typically involves groups of children engaged in pretend play that includes common goals, planning, role-play, interactive social dialogue and negotiation, improvisation, and the use of generic props as opposed to realistic toys [13–16]. Play is based on stories familiar to all children involved. The children negotiate and plan who will play each role. During play, adults should scaffold play activities to guide the children to purposefully collaborate with their peers (e.g., planning play activities) and play based on the story context [16] (p. 146).

The ideas behind *ToM* come from Vygotsky and his students Elkonin and Leont'ev. They emphasized the role of social interaction and external tools in child development [16, 85]. Vygotsky viewed the development of skills and concepts as occurring first socially (with help from others) and then individually [85], hence the strong *ToM* emphasis on teachers supporting coordination and other social aspects of play [16] (p. 145).

Within this view, Vygotsky saw a special role for sociodramatic play. He thought that when children pretend to be a character in a story, they regulate their behavior, behaving in ways consistent with the character and avoiding behaviors that would not fit the character or play context. As such, sociodramatic play could provide an entertaining approach for children to practice regulating their behavior in a myriad of ways [16, 85]. This self-regulation starts with physical behaviors followed by social behaviors and then by cognitive processes (e.g., attention) [16].

Vygotsky also valued the role of tools and symbols in children's development [85], which inspired the use of generic props as opposed to toys that look like specific items in *ToM* [16]. The use of generic props, such as foam blocks, enables children to use and reuse the props to represent different objects based on the needs of play [16]. Vygotsky hypothesized that this can help children develop abstract thought [85].

Multiple large studies provide evidence of the positive impact of the *ToM* curriculum on children's EF skills and academic achievement [10, 11, 26, 28, 59]. Bodrova and Leong report on studies conducted primarily in the Soviet Union to support their approach [16], and more recent studies replicate those results with contemporary children in the United States (e.g., [10, 26]). There may even be additional benefits to sociodramatic play activities in the style of *ToM*, such as increased creativity, as suggested by Mottweiler and Taylor's study with children age 4-5 [59]. Barnett et al. conducted a study with 210 children age 3-4 [7] and found improvements not only in children's EF, but also in classroom quality based on the Early Childhood Environmental Rating Scale-Revised for children who participated in *ToM* when compared to peers who continued with their school's standard curriculum.

ToM implementation can be challenging due to the non-trivial amounts of necessary training (e.g., five full days plus biweekly in-class check-ins [12]) for adult facilitators (typically teachers) needed to address challenges such as helping children plan play, coaching children who need help, and encouraging children to have positive interactions with each other [16] (p. 145). This presents an opportunity to lower barriers to *ToM*.

3 LOWERING BARRIERS WITH STORYCARNIVAL

StoryCarnival supports sociodramatic play in the style of *ToM* to help children develop a broad set of EF skills [62]. *StoryCarnival* was designed over 39 sessions working with two groups of 3-4-year-old children [62]. The current version of *StoryCarnival* consists of an app with interactive stories to introduce children to characters of equal importance and story settings on which to base play; a play-planning tool; and a facilitator-controlled, tangible voice agent to engage the children during play [62].

3.1 Stories

ToM-style play requires all participating children to have a common understanding of a story on which to base play [16]. This common understanding helps children establish common goals for play and facilitates communication among children [6, 69, 70]. Stories in children's books, movies, and television typically include one or two main protagonists, making it difficult to set up *ToM*-style play because most children want to play the protagonist(s). In addition, the *StoryCarnival* developers noticed that there were few stories that all children knew [62]. *StoryCarnival*'s solution to this barrier is to provide interactive stories with characters who all have similar importance, each with a different skill that is helpful in the context of the stories.

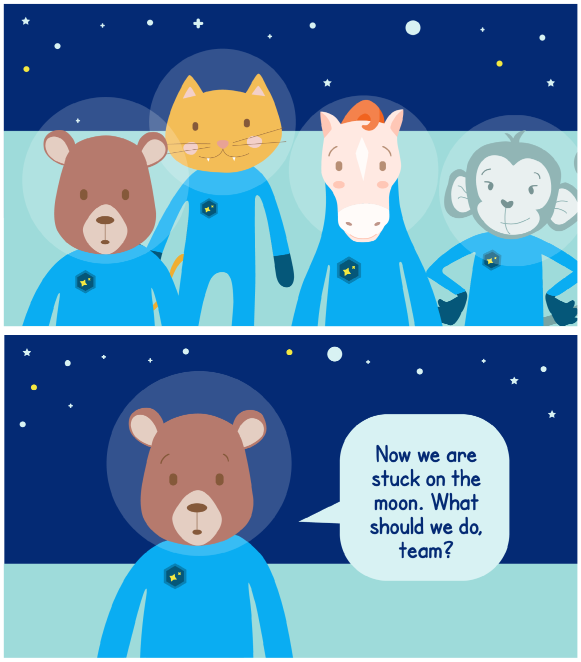

Figure 1: Screenshots from the Space Explorers story.

Figure 2: Screenshots from the play planner corresponding to the Space Explorers story showing the initial screen and the screen shown when Horse is selected.

The stories can be experienced as an e-book, showing one page at a time, with narration and character speech included as part of the story (both generated through Amazon Polly's speech synthesizer), together with speech bubbles as recommended by best practices [68]. Every story presents each character's special skills and provides examples of how they can help each other. While the stories set up a context, some challenges, and characters, they do not provide resolutions. This encourages children to develop their own resolution for each story through role-play. See Figure 1 for screenshots of the *Space Explorers* story.

3.2 Play Planning

Another barrier the *StoryCarnival* developers noted was that planning play could be difficult because children did not always remember the traits of story characters [62]. The play planner part of the *StoryCarnival* app shows the characters to choose from and upon selection states the character's skills. The play planner also uses Amazon Polly's speech synthesizer to generate character speech. See Figure 2 for screenshots.

3.3 Keeping Children Engaged Through Tangible Voice Agents

Without continuous support during play, the *StoryCarnival* developers found that sometimes children would drift away from the story theme or stop playing collaboratively with other children [62]. While facilitator intervention is an option in these situations, they wanted to provide support through technology in a way that would be less disruptive than an adult's intervention. They explored the use of tangible voice agents, which can support play without obstructing physical or social activities. They noticed several positive impacts on children's social play. The first was that children acted as mediators of the voice agents, asking other children, for example, to help the voice agent with a request [62]. The second was that voice agents promoted social interactions with peers [62]. The third was that voice agents could redirect children's behavior to re-engage with play [62]. When children listened to a voice agent, they tended to reply to prompts by either conversing with the agent or acting on its suggestions. Making voice agents tangible enabled children to incorporate them into their play, placing them inside constructions made from props, augmenting them with other props, and expressing affection toward them through hugging or petting [62].

4 RELATED CHILD-COMPUTER INTERACTION WORK

4.1 Agent-Based Research with Young Children

Children can interact with various forms of agents which range from voice assistants to screen-based agents to various forms of physical objects, including robots. Researchers studying commercial voice assistants have found children use them to explore interactions, seek information, or make requests [31, 53] with challenges related to poor speech recognition [31, 53, 67] and difficulty communicating [21, 54, 90]. There are also hundreds of voice-based apps marketed as learning apps for children [88], as well as educational apps designed by researchers [89]. Research on smart dolls and robots has found children are interested in communicating with them [32, 57] and respond to the toys' use of humor, praise, and affection [76, 77], autonomous behavior [48], and ability to remember prior events [2, 50, 51]. Researchers have also identified privacy concerns [18, 57].

The use of tangible voice agents in *StoryCarnival* differs from the research above in its reliance on adults to control the voice agent. This mitigates privacy concerns and difficulties with communication, enables agents to demonstrate contextual knowledge and personified characteristics, and enables a great deal of flexibility in the type of activities that can be conducted. At the same time, the *StoryCarnival* voice agent leverages the tangibility that others found beneficial [20], while using a minimal physical representation of a character, consistent with prior findings that there is no need for characters to look realistic to elicit interest from children [46].

4.2 Other Interactive Technologies to Support Children's Development of Executive Functions

Researchers have developed a number of technology-supported games and systems to help children develop EF skills [39, 64, 75, 86, 92], however the majority of these focus on improving performance on a specific task using a specific skill, and successful transfer of skills developed with these types of training programs appears to be limited [28, 29]. The approaches to developing EF skills in these other projects differ from *ToM*, which, as noted in Section 2, has been empirically shown to help children develop a broad set of EF skills.

5 RESEARCH GOAL

Pantoja et al. based the design of *StoryCarnival* on the principles of *ToM* but did not formally compare the characteristics of children's play using *StoryCarnival* to those of children's play using *ToM* without technology supports [61, 62]. We conducted this eight-week study as a first step in the formal evaluation of *StoryCarnival* to identify major differences in children's behavior during *ToM*-style play with and without the supports provided by *StoryCarnival*. Comprehensive evaluations of impact on EF typically require daily activities for months [10, 11, 26, 28, 59] and would not be justified before better understanding *StoryCarnival's* impact on children's behavior during *ToM*-style play. We also did not think it was appropriate to deploy *StoryCarnival* in schools to evaluate teacher training needs prior to conducting this evaluation.

In this paper, we focus on the analysis of children's on and off-task behavior. *ToM* specifically emphasizes providing support to children when they get off-task by not playing a role related to the story setting, not talking to each other as they play, or being unable to continue a story thread [16].

6 RESEARCH SETUP

6.1 Participants

Our participants were five 3-year-old children (3 girls, 2 boys) and twelve 4-5-year-old children (6 girls, 6 boys) from a preschool in a city with a population of about 100,000 in the United States. We sent recruitment packages to participants' parents through their teachers. In addition to obtaining informed consent from parents, children only participated in sessions if they wanted to and could interrupt their participation at any time. Parents filled out a demographic information survey, and we summarize the results of those surveys below.

In the 3-year-old group, participants were 42-45 months old at the beginning of the study. Four used tablets 10-60 minutes per day, primarily to use media (video streaming) and educational apps. Only one child used a voice assistant, mainly to play music for a negligible amount of time per day.

In the 4-5-year-old group, ten of the children were 4 years old at the beginning of the study (50-56 months) and two were 5 years old (61 and 65 months). Seven of the 4-5-year-old children used tablets 12-60 minutes per day (M = 20), also primarily to use media and educational apps. Two of the children in this group used voice assistants 5-15 minutes per day to play music and check the weather forecast.

6.2 Design

We conducted the study over eight weeklong phases, half of which used standard *ToM* procedures with no technology supports (A phases), and the other half supported by *StoryCarnival* (B phases). We randomly ordered the phases (order: A, B, B, A, B, A, A, B), and children participated in two sessions during each phase. We typically conducted sessions on Mondays and Thursdays (one session moved to a Tuesday, and another moved to a Friday). We considered evaluating each component of *StoryCarnival* separately, but we thought it made sense to evaluate all the supports previously identified by researchers together and follow up with further studies identifying the impact of each component if necessary.

6.3 Materials and Procedure

We conducted all sessions at a local preschool between October and December of 2019. All activities took place in a quiet spare room at the preschool. We conducted the activities just before parents would pick up their children. Teachers suggested this schedule to avoid conflicts with planned educational activities. Children came into the room with a teacher or aide who stayed to observe the activities. All five researchers who participated in sessions had prior experience working with children. Two had experience facilitating *ToM*-style sociodramatic play for more than two years and another had reviewed a significant amount of video material of *ToM*-style sociodramatic play. Children participated in sessions only with children in their same age group (i.e., the 3-year-old group never interacted with the 4-5-year-olds). Sessions typically lasted about 25 minutes. We video and audio recorded every session.

All sessions began with children experiencing a story, facilitated by one researcher. During A phases, we used stories from the *Detective Dinosaur* series. We identified these stories as both appropriate for the age group and for *ToM*-style play because they had multiple characters. The specific stories we used were: "The Case of the Missing Hat" and "Night Patrol" from *Detective Dinosaur* [71], "Lost" and "Found" from *Detective Dinosaur Lost and Found* [72], and "Under the Weather" from *Detective Dinosaur Undercover* [73]. Even with the help of three children's librarians at a large public library, it was difficult to identify age-appropriate books with multiple characters that could lend themselves to *ToM*-style play. However, we chose to go with existing stories rather than non-electronic versions of *StoryCarnival* stories to be faithful to how *ToM*-style play is typically facilitated. During B phases we used stories delivered through the *StoryCarnival* app: *Party*, *Castle in the Woods*, *Castaways* (two parts), and *Space Explorers* (two parts). During A phases, a researcher read from a book; during B phases a researcher showed children the stories using an iPad (4th generation). The researcher delivering the story to the children also asked questions, typically after each page to emphasize the content of the story. Often-asked questions included: "What do you think will happen next?" or "How do you think [a character] is feeling?" Regardless of the phase, the story-experiencing portion of the activity lasted about five minutes.

After experiencing a story, the 3-year-olds stayed in their group of five with two researchers, while the 4-5-year-old group split up into smaller groups which were more appropriate for play activities. The 4-5-year-old children's teacher or aide assigned them to groups for each session, mainly to avoid having children who did not get along in the same group. During the first two phases (one A and one B phase) the 4-5-year-old group split into two groups of six, each with two researchers in support. During the rest of the phases the 4-5-year-old group split into three groups of four, one supported by two researchers, and two each supported by one researcher. We made this change because we found it challenging to keep six children socially engaged in the same group and because prior work with *StoryCarnival* found that groups of four children were ideal [62].

The children then selected characters to play, prompted by a researcher. This oftentimes involved some negotiation between children and facilitation by adults. During A phases, one researcher asked children one at a time which character they wanted to be, often having to remind children of the available characters and their roles. During B phases, the children selected characters using the play-planning portion of the *StoryCarnival* app. The play-planning portion of the activity typically lasted two to four minutes.

After selecting roles, children played with each other, using generic props (e.g., foam shapes, hats), pretending to be characters in the story. In A phases, the researchers interacted directly with children, guiding them to play together and stay within the make-believe context, and sometimes joining in play. In B phases, if there were two researchers available, one played the same role researchers played in A phases, while the other one controlled the speech of a voice agent we referred to as MiniBird. If only one researcher was available, they played a hybrid role of interacting directly with children while also controlling MiniBird. MiniBird is made of laser-cut layers of cardboard glued together (8.57cm x 8.57cm x 7.62cm), a Bluetooth speaker, and artwork to give it its appearance (see Figure 3). The researchers controlling MiniBird could type text in an app that would produce speech through the Bluetooth speaker using the Amazon Polly speech synthesizer. This portion of the activity lasted about 15 minutes before children needed to get ready to go home.

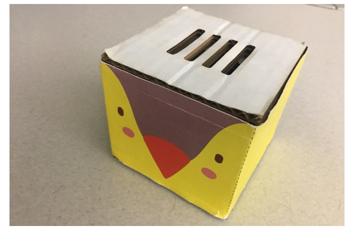

Figure 3: The MiniBird voice agent.

7 DATA ANALYSIS

We conducted three types of content analysis of the video recordings of sessions: a conventional approach in which we categorized observations, a summative approach in which we quantitatively analyzed transcripts, and a directed approach in which we coded for specific behaviors [45]. In the following paragraphs we explain each approach in detail.

To conduct our conventional content analysis, the three most senior researchers watched the video recordings of the sessions. At least two of these researchers watched each of the video recordings. The researchers independently wrote open-ended observations on 894 sticky notes and organized them in an affinity diagram to extract themes using Lucidchart [60]. The sticky notes were color-coded to distinguish between observations made during A and B sessions and coded by shape to distinguish between the 3-year-old group and the 4-5-year-old group. In addition, they included a reference to the specific session in which the observation was made. Given the volume of sticky notes involved, it took several meetings between the three researchers to organize all sticky notes into sets of themes and subthemes. When we refer to these observations in the results, we note the session(s) corresponding to an observation with labels denoting age group, whether it was an A or B session, and the session number (e.g., "3B05" refers to a 3-year-old B session numbered 5). For the 4-5-year-old observations, we also use "x", "y", or "z" to distinguish between the different groups of children in which the behavior was observed during a given session (e.g., "4B06x, 4B06y" would indicate that the behavior was observed in two 4-5-year-old groups during a B session numbered 6).

For the summative approach, three other researchers transcribed the video recordings using a consistent pseudonym scheme for each participant. These researchers transcribed speech as consecutive lines by the same person if there was a clear pause waiting for a reply between lines or a clear change in subject. Another researcher wrote Python scripts to process the transcripts and calculate the number of lines and words each child, facilitator, and MiniBird spoke during each session and whether lines mentioned MiniBird. The scripts also calculated the average lines and words per minute by category of speaker for each session (i.e., children, facilitators, MiniBird). To better understand children's patterns of verbal exchanges the scripts calculated, on a per-child basis, the number of times children spoke after other children, a facilitator, or MiniBird. For each of these instances the script also tracked how many times each category of speaker (facilitators, MiniBird, or other children) spoke in a row before a specific child responded. With these calculations we sought to learn whether there were differences between conditions in who children responded to and how many times they spoke before children responded. This use of transcripts is relevant given the *ToM* goal of children speaking to each other as they play [16] (p. 151).

For the directed approach, two coders used BORIS [37] to code specific behaviors observed in the video recordings of each session for the 3-year-old group's videos and 15 of the 4-5-year-old group's videos. They coded each video together, ensuring agreement on all codes. A different researcher coded the remainder of the 4-5-year-old group's videos in addition to a randomly selected video out of the 15 already coded, achieving a Cohen's Kappa value of .71. The researchers coded for the following: time off-task (as defined by [16]), number of distinct symbolic uses of props, and for B phases, the amount of time children spent physically engaged with the voice agent (i.e., holding or putting props on the agent).

We conducted the statistical analysis of the data extracted from the transcripts and the coding of specific behaviors using SPSS 25. We checked each variable for normality using the Shapiro-Wilk test and for sphericity using Mauchly's test. If the data was normal and the sphericity assumption was not violated, we used repeated measures ANOVAs (we report means, standard deviations, F, and p values, as well as, $\eta^2{}_p$ for effect size where .0099, .0588, and .1379 are used as benchmarks for small, medium, and large effects [65]) and otherwise used Friedman's test (we report medians, X^2, and p values, as well as Kendall's w for effect size [83]). In addition, we graphed data and carefully analyzed descriptive statistics given the relatively small number of children and sessions, which may not always yield statistically significant results for findings worth reporting.

8 RESULTS

8.1 Children's On-Task Behavior

As stated under our research objectives, *ToM* on-task behavior involves children playing a role related to the story setting, talking to each other as they play, and continuing story threads [16] (p. 151). The three types of content analysis we conducted suggest that children were more likely to be on-task during *StoryCarnival* sessions (B sessions) than traditional *ToM* sessions (A sessions). In our directed analysis, the percent of coded time off-task per child during A sessions was statistically significantly higher than during B sessions (see Table 1). We found additional evidence of children's greater on-task behavior during B sessions in our analysis of transcripts through several statistically significant results. We report the results of tests comparing children between A and B sessions in Table 1 and results of tests comparing children and facilitators in Table 2. Our conventional content analysis identified a theme of off-task children typically being quiet, especially during A sessions (3A13, 3A14, 4A01y, 4A02y, 4A07z, 4A08x, 4A08y, 4A11z, 4B03y, 4B04y, 4B06x, 4B06z).

In sessions with 3-year-old children, the children cumulatively spoke more lines per minute during B sessions than A sessions (see Table 1). In addition, they spoke more lines per minute in B phases than the combination of facilitators and MiniBird (see Table 2). These findings point not only at a greater amount of verbal engagement by children in B sessions, but at this engagement surpassing that of the facilitators and MiniBird (see Figure 4). In sessions with 4-5-year-old children, the children cumulatively spoke more lines per minute than facilitators in both A and B sessions, even when including MiniBird lines in the latter (see Table 2, Figure 4). However, this difference was greater between children and the

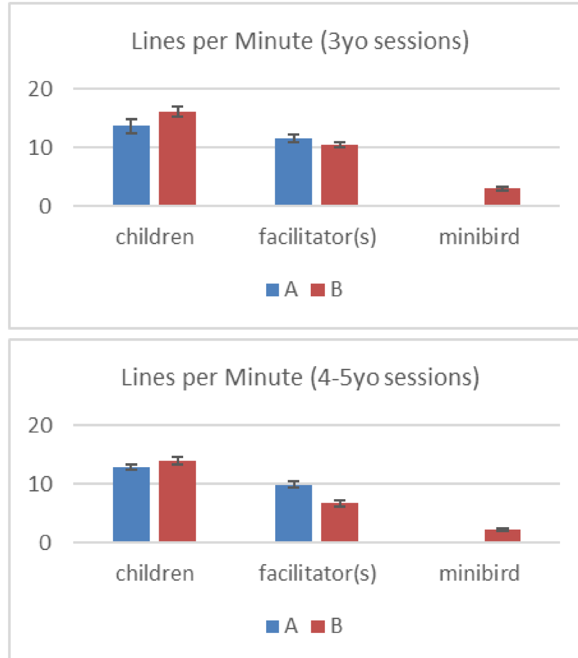

Figure 4: Lines per minute for 3-year-old sessions on the top and 4-5-year-old sessions on the bottom. Bars correspond to mean values and error bars are two standard errors long. To calculate children values, all lines spoken by children during a session were added and divided by the length of the session. Similarly, if multiple facilitators were in a session, all their lines were added, then divided by the length of the session.

combination of facilitators and MiniBird during B sessions than between children and facilitators during A sessions. In addition, 4-5-year-old children cumulatively had more instances per minute of speaking after another child in B sessions than A sessions (see Table 1). The average number of lines spoken by other children before a child spoke was also greater in B sessions than A sessions (see Table 1). Both statistically significant findings suggest children had greater engagement with each other during B sessions than A sessions. Note that given the high number of lines per minute spoken, there were almost constant verbal exchanges during play, but children played a greater role in those verbal exchanges during B sessions.

8.2 Integration of Shy Children

In our conventional content analysis, we identified a theme of children engaging in play when given a turn with MiniBird (4B04x, 4B05z, 4B06z, 3B10, 3B15, 3B16). We found supportive data in our transcripts when we analyzed the difference in lines per minute and words per minute for individual children between A and B sessions. We found that both lines per minute and words per minute had a statistically significant correlation with the percent of child lines that included a mention of MiniBird (Spearman: lines per

Table 1: Comparisons between children's behavior under the two conditions.

Measure	Age	Mean/Median A	Mean/Median B	Stat	p-value	Effect size
% time off-task	3-5	9.65, (SD=8.31)	6.37 (SD=5.68)	F(1,29)=5.191	.030	$\eta^2{}_p = .152$
Lines/minute	3	13.65 (SD=3.320)	16.09 (SD=2.665)	F(1,7)=7.695	.028	$\eta^2{}_p = .524$
Child speaking after another child/minute	4-5	4.432 (SD=1.657)	6.584 (SD=2.150)	F(1,21)=13.33	.001	$\eta^2{}_p = .388$
Lines by other children before child speaks	4-5	1.443	2.018	X^2=8.909	.003	Kendall's W = .405

Table 2: Comparisons between children and facilitators (and MiniBird for B sessions) within a particular condition.

Measure	Age	Phase	Child mean/median	Facilitator + MiniBird mean/median	F	p-value	Effect size
Lines/minute	3	B	16.09 (SD=2.665)	13.34 (SD=1.416)	F(1,7)=9.882	.016	$\eta^2{}_p = .585$
Lines/minute	4-5	A	12.84 (SD=2.414)	9.874 (SD=2.589)	F(1,21)=36.73	<.001	$\eta^2{}_p = .636$
Lines/minute	4-5	B	13.98 (SD=2.872)	8.852 (SD=2.935)	F(1,21)=76.99	<.001	$\eta^2{}_p = .786$

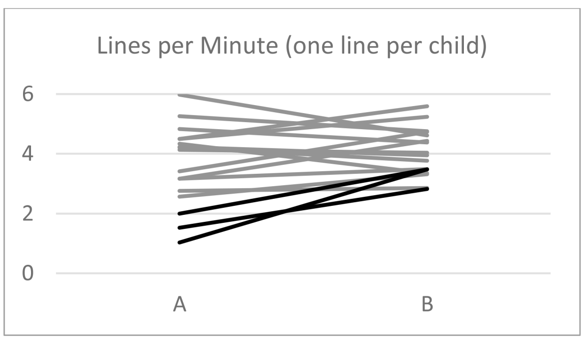

Figure 5: Mean lines per minute for each child for A (no technology) and B (*StoryCarnival*) sessions. We use darker lines for children who were least verbally participative during A sessions.

minute r(17)=.579, p=.015, words per minute r(17)=.596, p=.012). In other words, children who mentioned MiniBird more often were more likely to increase their lines and words per minute between A and B sessions. This increase in verbal participation matters given our finding (in Section 8.1) that children who were off-task tended to be quiet. Figure 5 illustrates how each child changed in terms of lines per minute between A and B sessions. Of note is that the range of lines per minute was reduced from 4.95 in A (no technology) sessions to 2.77 in B (*StoryCarnival*) sessions, suggesting children had more equal participation during B sessions than during A sessions.

Figure 5 also shows how children who were least likely to verbally participate in A sessions increased their participation during B sessions. One of our conventional content analysis themes was how MiniBird interactions were particularly beneficial to the integration of children who appeared shy based on verbal participation and the presence of reticent behaviors during peer interactions and had a difficult time joining play. More specifically, we identified one 3-year-old child, and two children in the 4-5-year-old group who fit this pattern (represented by darker lines in Figure 5). We did not find any evidence in our observations that other children intentionally excluded these shy children during play, but rather that MiniBird motivated shy children to engage in play more actively than they did in A sessions as described in Section 8.3. During A sessions facilitators made repeated attempts to engage these three children in play, which largely were not successful (3A01, 3A07, 3A11, 3A12, 4A01x, 4A07x, 4A08x). However, engaging them through MiniBird worked (3B04, 3B10, 4B04x, 4B09z, 4B09x). The 3-year-old child had 219% more lines per minute in B than A sessions and his share of lines among children was 123% higher. The two 4-5-year-old children did not display as dramatic a difference between A and B sessions, but still had 59 and 70% more lines per minute in B than A sessions, accompanied by increases in their share of lines among children of 46 and 56% respectively. All three children also showed increases in the number of words per spoken line (34%, 51%, and 14% respectively). We describe each child's interactions with MiniBird in more detail in Section 8.3.

We conducted linear regressions with session number as the independent variable and lines per minute as the dependent variable to assess novelty effects on these three children. We list results that were statistically significant or near statistical significance in Table 3. The 3-year-old child (pseudonym Lucas) steadily increased his lines per minute as B sessions moved forward, with the trend near statistical significance; the mean lines per minute in his last two

Table 3: Linear regressions with session number as the independent variable (x) and lines per minute as the dependent variable (y). We list cases with statistically significant, or near statistically significant results.

Child	Phase	F, p	Equation	R^2
Lucas	A	F(1,5)=12.338, p=.017	y = -.16x + 1.52	.71
Lucas	B	F(1,4)=6.294, p=.066	y = .63x + .58	.61
Roo	B	F(1,6)=7.249, p=.036	y = .41x + 1.06	.55

B sessions was 260% higher than that in his first two B sessions. During A sessions, he had a statistically significant decline in lines per minute as sessions proceeded (see Table 3). The two 4-5-year-old children did not show clear trends as A sessions progressed (p>.4), perhaps due to that age group changing peers between sessions. One of them (pseudonym Roo), did show a statistically significant increase in lines per minute as B sessions proceeded (see Table 3), but the other one (pseudonym Kanga) did not (p>.4). We also conducted linear regressions with session number as the independent variable and lines per minute and time off-task as dependent variables separately for A and B sessions and for 3- and 4-5-year-olds for all children combined and found none were near statistical significance. This analysis suggests no evidence of a novelty effect at play, instead suggesting that the impact of *StoryCarnival* may increase over time for shy children.

8.3 MiniBird Interactions

Through our conventional content analysis, we identified three primary types of interactions children had with MiniBird: expressing affection for MiniBird, repeating MiniBird's speech, and caring for MiniBird's needs. All three shy children expressed affection for MiniBird as their peers did, but their engagement in play seemed to depend more directly on the other two categories of interactions.

The 3-year-old, Lucas, took on a role within the group of 3-year-olds as MiniBird's mediator, repeating what MiniBird said to ensure other children heard it. Additionally, after repeating a suggestion MiniBird made, Lucas tended to follow through on the suggestion and respond according to his character's role. This role of MiniBird's mediator allowed Lucas to play with the group in stark contrast to his behavior during A sessions. This example from session 3A01 shows facilitators unsuccessfully trying to engage Lucas:

R1: What do you think? Get the kitty out of the bag? Officer Pterodactyl gets it out of the bag and says. . . (offers the "kitty" to Lucas)

R3: Do you want to take it?

Lucas: [nonverbal]

R1: Do you remember what happened?

R3: Go ahead and take it.

Lucas: [nonverbal]

R1: He said meow!

R3: You can take it.

Lucas: [nonverbal]

This example from session 3B04 shows MiniBird successfully integrating Lucas in play through repetition:

MiniBird (to Lucas): Horse, can you drive us to the store?

R1 (to group, overlapping with MiniBird): Can we make a cake together?

Lucas (holding up MiniBird): He said he needs a driver.

R1: That's you! Where do you want to take him?

MiniBird: What can the drivers get from the store?

. . .

Jim: I got a big cake!

Lucas: And I have a shoe cake.

Like Lucas, Roo initially engaged with MiniBird and the group by repeating MiniBird's suggestions and following up on them. However, after the first few *StoryCarnival* sessions, Roo began to engage with his character's role more independently, without much prompting from facilitators or MiniBird. This example from session 4B15z shows Roo taking ownership of his character's role as a grower:

(Dora picks up a block that Roo just pretended to plant)

Roo: No! That was a seed, Dora!

R3: That was a planted seed.

Roo (guiding Dora's hand to replant the seed): Here, let's pretend you buried it super deep.

R3: So, we buried it super deep so when it grows it will look like this (mimes).

Roo: Yeah, but now we need green [blocks] because we're growing cherry tomatoes.

Both Lucas and Roo had favorite types of character roles to play in *StoryCarnival* sessions. However, the influence of these preferences on their engagement in play appears secondary to MiniBird's influence. Lucas consistently chose to be the driver from *StoryCarnival* stories but did not choose to be the taxi driver in "Lost" from *Detective Dinosaur Lost and Found* when presented with the chance. If the driver role alone was responsible for Lucas' integration in *StoryCarnival* sessions, we would have expected to see similar outcomes in A sessions when Lucas could play a driver. Roo tended to choose the role of the builder in *StoryCarnival* stories, but as illustrated in the above excerpt, he took on the role of the grower in a story which presented him with the option to play as a builder.

Rather than repeating what MiniBird said, Kanga tended to engage with MiniBird through caring behavior, especially behaviors related to food and feeding. This example from session 4B05x illustrates Kanga's engagement in group activities centered around caring for MiniBird:

Kanga: MiniBird, are you allergic to dairy?

MiniBird: No.

...

Piglet: MiniBird, we're making pizza for you!

Kanga: Lemon on pizza!

Bruce: Rubbing the sauce out!

Kanga: This is sauce! Ooh sauce! Sauce!

However, Kanga appeared to expect a certain level of intimacy with MiniBird. In session 4B09z, Kanga whispered to MiniBird and became upset when MiniBird did not respond to her because the researcher controlling MiniBird could not hear what Kanga whispered. This led Kanga to say, "MiniBird is being mean." We observed this desire to speak one-on-one with MiniBird and subsequent frustration more broadly in the 4-5-year-olds (4B06z, 4B09z, 4B10y). Perhaps if MiniBird responded to Kanga's whispering as she expected, her verbal engagement would have increased over time in B sessions as Lucas and Roo's did.

Still, it is significant that while MiniBird had a clear role in engaging these children in play, the overwhelming majority of their verbal exchanges during B sessions were with other children and facilitators, not with MiniBird. Only 7% of the 3-year-old child's lines during B sessions came after MiniBird spoke. The two 4-5-year-old children each spoke 9% of their B session lines after MiniBird. In other words, while MiniBird inspired and encouraged engagement, children did not depend on MiniBird to verbally interact with others.

9 DISCUSSION

9.1 Support for Shy Children

MiniBird especially appeared to help shy children engage in sociodramatic play with their peers. We did not plan to draw a distinction between shy and more outgoing children when we designed our study, but we observed behaviors indicating shyness in 3 out of 17 children (17%). This appears consistent with research in developmental psychology which classifies approximately 15% of young children as behaviorally inhibited [24]. Behaviorally inhibited children have an increased risk of developing anxiety disorders later in life [24]. Chronis-Tuscano et al. argued this risk may be reduced by encouraging young children to engage in productive social interactions with their peers and that interventions should occur within the context of a child's interactions with peers [22]. Chronis-Tuscano et al. also stressed the need for more research on the incorporation of technology into prevention and treatment plans for children who are at risk for developing anxiety disorders [22].

Prior HCI work has demonstrated the potential for VR, robots, and serious games to help alleviate anxiety in older children, with or without anxiety disorders [19, 49, 52, 56, 80, 91]. Patwardhan et al. developed an application designed to support early intervention for children at risk of developing anxiety disorders [63]. A few short HCI works have investigated support for shy children (e.g., [1, 40, 82]), but this appears to be a largely underexplored area within HCI. The results of our evaluation provide evidence supporting a new line of investigation: the potential for voice agents to support early intervention strategies for shy children.

Hipson et al. found that active emotion regulation (e.g., regulation through intentional planning and problem-solving) mediates the relationship between shyness and preschoolers' social adjustment: active emotion regulation leads to better social adjustment, and shy children are less likely to employ these regulation strategies [41]. This suggests that the development of EF skills may improve shy preschoolers' social adjustment. Based on our observations of children's interactions with MiniBird, we believe technological supports like those used in *StoryCarnival* could play a critical role in lowering barriers to programs like *ToM* which rely on social play and helping shy children develop the EF skills needed to engage with their peers more independently. Specific opportunities for research include incorporating ideas from existing interventions (e.g., [22, 24]) for shy children into tangible voice agent interactions, expanding tangible voice agent use to activities beyond *ToM*, understanding how to best manage sharing of the tangible voice agents among children to ensure shy children are able to benefit from it, and transitioning children away from agent support to participate in social activities more independently.

9.2 Why Did MiniBird Help Engage Shy Children?

Why would MiniBird provide an advantage in engaging shy children in play? We think voice agents empower facilitators by providing an alternative way of communicating with children through an item with which children relate in a different manner than they do with an adult. Children acted as mediators for MiniBird, held it, were inclined to take care of its needs, and could incorporate it into their play, including the structures they built. None of this occurred with the adult facilitators. Adult facilitators could also do things that were not possible with the current implementation of MiniBird, such as modeling how to play, pointing at items or locations, and so forth. The combination of both avenues of communication with children provided advantages over having only one type of communication. The advantage of having a tangible voice agent is that it also enables children to focus on the social and physical aspects of play, unlike what would happen with a screen-based or static agent. Additionally, in our implementation, MiniBird did not have to take a central role in verbal interactions to have an impact on children's participation in play. If MiniBird made a suggestion children liked, they would play based on that suggestion and build off it without needing additional input from MiniBird. These characteristics of tangible voice agents suggest that they could prove useful in supporting other collaborative, creative, physical activities for children. At the same time, the results do not mean that any tangible voice agent would have achieved the same results. The design of MiniBird was based on 39 design sessions with other groups of children of the same age [62], and other efforts aiming to obtain similar results would likely require a similarly careful and inclusive process for designing tangible voice agents.

9.3 Limitations

The study involved a relatively small number of children, all from the same school. It is possible that a larger and more diverse group of children would have yielded different results. At the same time, the size of the group enabled a more detailed analysis of sessions, which we find appropriate at this stage. The study also did not test each component of *StoryCarnival* separately. For this initial evaluation we wanted to learn whether all the components together could have an impact. We analyzed other factors in our evaluation, but due to page limits we focused this paper on what we thought was the most salient finding: MiniBird's ability to help incorporate shy children.

9.4 Future Work

One of the most encouraging aspects of the study was seeing children who otherwise had great difficulty participating integrated into play. Future work could specifically investigate the impact of such a system on shy children's play with other children they do not know or whether such a system could reduce exclusionary behavior during play. In addition to support for shy children, we believe this observation points at an opportunity to explore the use of voice agents with neurodiverse children who may have difficulty joining group activities. It would be useful to see if the use of tangible voice agents could provide a scaffold for these children to communicate with peers and take part in social activities. Previous HCI research has indicated that tangible devices show potential to support inclusion (e.g., [35, 36, 38]) and provides methods for measuring inclusive play (e.g., [8, 43, 44, 74, 87]).

Given the results of this evaluation, a larger-scale, more intensive study of *StoryCarnival*'s impact on children's EF skills could prove useful. There were some differences in the way children engaged with *StoryCarnival* compared to traditional *ToM* activities, although we observed the key components of *ToM*-style play in children's engagement with *StoryCarnival*. A larger study could more closely follow the approaches taken to evaluate *ToM*'s impact on EF skills (e.g., as used in [10, 11, 26, 28, 59]).

10 CONCLUSION

In this paper we presented the results of a study suggesting that the technology supports in *StoryCarnival* may help keep 3-5-year-old children more engaged in *ToM*-style play when compared to conducting the same activities without technology supports. More specifically, *StoryCarnival's* tangible voice agent helped incorporate shy children into play. The study opens the door to future research on social skills and inclusion for shy children, as well as extending the use of *StoryCarnival* to other populations that may benefit from it.

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SELECTION AND PARTICIPATION OF CHILDREN

Our university Institutional Review Board (IRB) reviewed and approved our research activities. Parents of participating children received a written invitation and mailed a signed informed consent form to us prior to their children beginning participation in our research activities. Children only participated in an evaluation session if they desired. If not, we gave them the option to observe. There was always a teacher present in the room. All research data is stored in secure cloud-based storage approved by our university's IRB.

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