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Changing Dynamics of Preschool Children's Social Play with Technology: Evaluation of Technology-Based Supports for Tools of the Mind Style Play

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ABSTRACT

In the context of a pandemic that has had wide-ranging negative impacts on preschool children's socioemotional development it is important to consider uses of technology to support children re-engaging socially with peers. In this article, we review the landscape of systems to support children's face-to-face collaboration and identify an underexplored approach that could be well suited for the current context: using technology in a peripheral role to support activities where the focus is on other children and non-electronic objects and where children are free to engage with the physical space around them with the support of adults. We then present a pre-pandemic evaluation of *StoryCarnival*, a system with these underexplored characteristics, designed to support preschool children's sociodramatic play, for which there is evidence of numerous benefits that can positively impact children's socioemotional development. The results of the evaluation comparing sociodramatic play with and without *StoryCarnival's* support suggest that while not being the focus of the activity, *StoryCarnival's* components changed the dynamics of play for the children in the study during our observations, such that children

displayed more mature play characteristics. Our discussion includes implications for child-computer interaction and considerations for the pandemic context.

1 INTRODUCTION

The great disruptions brought to children and their families by the COVID-19 pandemic have had a negative impact on many children's socioemotional development, with consistent reports of stress, anxiety, and depression, as noted in systematic reviews [1,2], and a wide range of studies and reports from all over the world [3–19]. For example, a German study surveying 1,923 children (7-17 years old) found about two-thirds were experiencing decreased quality of life and higher anxiety levels both in May/June 2020 [17] and December 2020/January 2021 [18]. A survey of 2,419 Italian parents of 8-18-year-old children found that close to a third of children were at high risk for post-traumatic stress disorder [9]. Studies focusing on younger children [5,10,12] found similar concerns with themes of social isolation, stress, and anxiety. These negative consequences add to already worrying pre-pandemic trends of increasing mental health crises among adolescents in the United States [20]. Given the strong evidence of social anxiety [21] during early childhood as a predictor of anxiety disorders later in childhood [22,23] and adulthood [24,25], we suggest that greater efforts should be made to help children re-engage socially in preschools, in particular with activities that may be protective of their socioemotional development.

This article centers around research on a system called *StoryCarnival* [26–28] that although developed prior to the pandemic, we believe has the necessary foundational components to contribute to addressing this urgent need. Pantoja et al. [26–28] designed *StoryCarnival* to lower barriers to an evidence-based practice, sociodramatic play in the style of the *Tools of the Mind* (ToM) approach to early childhood education [29]. In this approach, the goal is for children to participate in "mature play," which is defined by the characteristics listed in Table 1. Researchers have conducted multiple large studies identifying the positive short and long-term impact of this type of play, including enhanced executive function (EF) and academic achievement [30–34]. Prior to the pandemic, other researchers had already linked EF deficits with anxiety [22,23,35,36], making it unsurprising that a study found negative behavioral impacts of the pandemic on young adults with lower EF [37]. Pandemic-era studies also found play and social integration with other children and family members to be a protective factor [12,19] and something children desired [38]. *StoryCarnival* aims to support an evidence-based practice that by enhancing EF and engaging children in social play has the potential to reduce harm for children at risk of having negative impacts in their socioemotional development.

1	Act out scenes within a pretend scenario instead of repeating actions.
2	Use props symbolically instead of using objects only realistically.
3	Play roles with specific characteristics instead of not playing within roles.
4	Use oral language to describe what they are doing with respect to play instead of minimal language.
5	Coordinate play with multiple roles instead of engaging in parallel play.
6	Discuss with each other what they are going to do next, as opposed to just doing it.
7	Solve disputes by inventing new roles for props instead of fighting over props.
8	Can continue play from prior sessions instead of only being able to engage in play for 5-10 minutes.

Table 1. Characteristics of mature play for Tools of the Mind approach to early childhood education [29].

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 (through speech suggestions and free text entry), tangible voice agent to engage the children during play [26]. *StoryCarnival* supports social play activities where the focus is on symbolic play with non-electronic props, other children, and the physical environment, with the ability for children to move around as they please, and technology in a supportive role, controlled by adult facilitators, aiming to inspire and sustain creative social play as inclusively as possible. We believe this approach to using technology to support evidence-based practices will not only be beneficial to children, but also more acceptable to parents and teachers than screen-based activities [39] or smart toys that gather data and process it remotely [40].

There are three reasons why we are using technology to support ToM-style play and why similar approaches could be pursued for similar evidence-based activities. The first is that successful implementations of ToM have required significant staff training and coaching [41], which is unlikely to be practical for most preschools. This is not an unusual barrier for evidence-based practices directed at young children [42]. *StoryCarnival* was designed to lower barriers to ToM-style play. The second is that technology could change the dynamics of these activities in ways that could provide benefits, such as, more mature play. The third is that because of the prevalence of technology use by children and concerns that this use might contribute to children's social isolation [43], we as human-computer interaction researchers have a responsibility to investigate whether other applications of technology may instead foster beneficial social engagement.

This article makes contributions with respect to the second and third reasons for using technology. First, if we are to consider technology to support face-to-face social activities for children, it is useful to understand the landscape of approaches to support face-to-face collaboration with technology. Our first contribution is a thorough survey of research from two key conferences where child-computer interaction research is published on technologies involving face-to-face activities. The survey reveals an underexplored space for technologies that support children's face-to-face activities, but that are not the center of attention of these activities, enabling children to focus on each other and on non-electronic objects, free to move around and interact with the physical space around them. This underexplored space, with technology on the periphery, supporting an evidence-based activity, is where *StoryCarnival* fits. The second contribution is an in-depth analysis of an 8-week pre-pandemic comparison of 3-5-year-old children participating in ToM-style play with and without *StoryCarnival*. Through this analysis, we investigate *StoryCarnival's* impact on the maturity of children's sociodramatic play including children's play coordination, the role of adult facilitators, and how children related to *StoryCarnival's* voice agent. Altogether, we provide examples of how *StoryCarnival* facilitated changes in the dynamics of children's play during our observations. For example, we found evidence of more coordinated play and more centrality to children's roles when using *StoryCarnival,* compared to when children played without technology supports. We also noted the variety of ways in which children interacted with *StoryCarnival's* facilitator-controlled voice agent that were different from how they interacted with facilitators. We expect that this contribution will motivate the exploration of novel uses of technology to manage the dynamics of children's face-to-face play such that it can be tuned to help children re-engage in social activities.

2 SURVEY OF SUPPORT FOR FACE-TO-FACE COLLABORATION IN THE CHILD-COMPUTER INTERACTION LITERATURE

If we are to consider the role of technologies in children's face-to-face activities, it is useful to understand the range of approaches that researchers have considered for supporting such activities. Researchers in child-computer interaction have long sought to go beyond computer experiences that involve one child and one device, designing systems that enable multiple children to work together face-to-face (e.g., [44]). There is also a broad literature on technologies supporting children's remote collaboration and communication, but that is outside the scope of this article. To get a better sense for the range of approaches for technologies to support children's face-to-face collaboration in the literature, we identified relevant publications from both the ACM Interaction Design and Children (IDC) conference and the ACM Conference on Human Factors in Computing Systems (CHI), two key conferences for research on child-computer interaction. This survey of conference publications is similar to others recently published at the IDC conference [45,46].

2.1 Method for Identifying Relevant Literature

We identified relevant works using Google Scholar and key words: face-to-face, collaboration, co-located, multi-user, social, computer-supported cooperative work (CSCW), and tangible. We searched for publications in two venues: the Interaction Design and Children (IDC) conference and the Human Factors in Computing Systems (CHI) conference. Our search included all articles published in these two venues between 1990 and 2020 (note that IDC did not start until 2002). The search for IDC and CHI publications identified 558 and 849 potential works respectively, which contained at least one of the relevant keywords for further analysis.

To arrive at a relevant set of publications, at least two researchers reviewed each publication and identified those that were full papers and described a system for use with children under the age of 18 to support co-located, face-to-face activities. Because of the emphasis on face-to-face communication, we did not include works supporting remote collaboration. To be considered a face-to-face collaboration system, the actions of any child within the course of the activity could not be completely independent of all other participants. For example, children independently using the same software in computer lab setting would not meet our selection criteria. For this reason, we excluded systems that supported multiple users within a shared space acting independently of each other. For cases where there were disagreements on whether to include a publication, the two researchers discussed the publication and, if necessary, discussed it with other members of the research team. As a result of this process, we identified 52 relevant publications from IDC and 29 from CHI. A list of the papers is in Appendix A.

Following the selection process, we analyzed the 81 papers using an open coding methodology [47] to identify areas of commonality, focusing specifically on the design of the technology supporting collaboration. We examined methods used by participants to interact with both the system and the surrounding environment, the extent (or role) to which adults were involved within the collaboration as part of the system, the proximity of the users within the activity for which the collaboration system was used, and the amount of attention devoted to the technology within the scope of the collaboration as part of the interaction with the system.

As we reviewed the articles, we noticed different approaches to supporting face-to-face activities and developed a categorization scheme to better understand the variety of approaches used, and the areas that are underexplored and that could potentially benefit children given the current context. The categories we coded for were the following:

Adult Involvement: Role of adults in the activity supported by the system (e.g., no involvement vs. active participation).

User Motion: Range of user motion related to the face-to-face activity (e.g., sitting at a desk vs. moving freely around a room).

Attention to Technology: Amount of focus devoted to technology (e.g., full attention vs. casual awareness).

Interactions with the Physical Environment: User interaction with the physical environment other than the system (e.g., interactions with non-electronic toys).

Three researchers separately coded seven papers based on the categorization scheme on a five-point scale. Following the independent classification, the researchers met to clarify any disagreements. A single researcher classified the remaining 74 papers. To demonstrate the consistency of the coding scheme, an inter-rater reliability analysis was conducted by having two different researchers independently code 9 randomly selected papers from the set of 74 paper coded by a single researcher. The Cohen's Kappa value of agreement between the coders was 0.740 (for the 108 codes assigned to 9 papers), which is classified as substantial agreement.

2.2 Survey Results

Below, we focus on cross-tabulations of the results to show combinations of characteristics that are prevalent and those that could be further explored. To simplify all following graphs we use the scale: -2 (Sparse), -1, 0 (Balanced), 1, 2 (Considerable). We mark *StoryCarnival* on each graph with a red 'X'.

When we examined the relationship between Adult Involvement and User Motion, there were few examples of systems that incorporated both considerable user motion and considerable adult involvement (see Figure 1). Systems with higher user motion tended to have low adult involvement, and vice versa. *MOGCLASS*, a system where a group of co-located children make music together using mobile devices with a high level of involvement from teachers, is an example of a system with low child motion and high adult involvement [48]. The *TagTiles* system involves children jumping up and down to generate energy necessary to play a game, requiring high levels of user motion, but little adult involvement [49]. The *pOwerball* mixed-reality game is an example of a system with low user motion and low adult involvement, featuring support for 2-4 child players on an augmented reality tabletop upon which the game's animations are projected [50].

StoryCarnival is one of a handful of systems that support children's ability to explore the physical space around them while having a high level of adult support. Such approaches may be beneficial for supporting activities that typically involve children being able to move around a physical space and that work better with adult support.

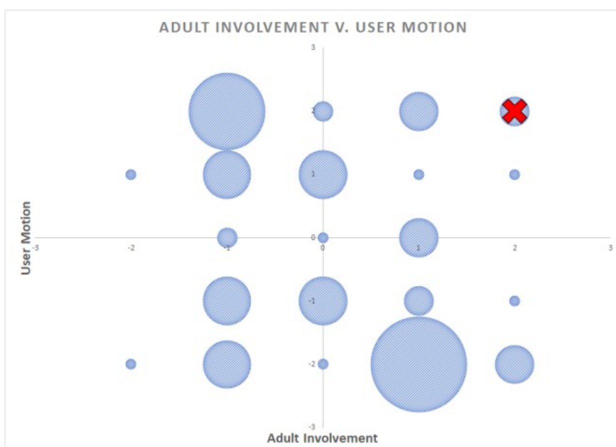

Figure 1: Distribution of papers based on adult involvement and user motion.

Our exploration, not surprisingly, revealed that high user motion related to low attention to technology (see

Figure 2), with most systems featuring high attention to technology and low user motion. Likewise, high user motion corresponded with more interactions with the physical environment (see Figure 3). Figure 4 clarifies that most systems tend to require a high level of attention to technology, which is associated with few if any interactions with the physical environment. A classic example of a system with low user motion, high attention to technology, and low interactions with the physical environment is KidPad [51], which involved children collaborating on a computer to design stories through the use of multiple mice. In general, all systems where children collaborate on a single screen, whether on a static display [44,51], a mobile display [52], a projection [53], or a tabletop [54], tend to have these characteristics. Some of these systems include the use of tangible user interfaces [55]. *StoryCarnival* is among a smaller group of systems that support children moving around the physical space while interacting with it, with their main point of attention being other children, adults, or non-electronic physical items. In these systems, technology is in a supporting role.

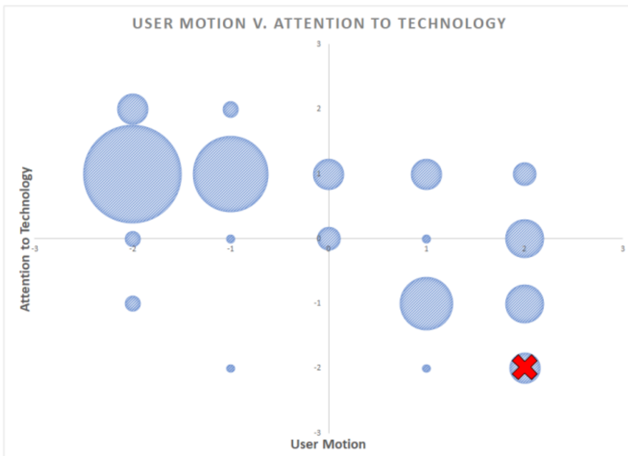

Figure 2: Distribution of papers based on user motion and attention to technology.

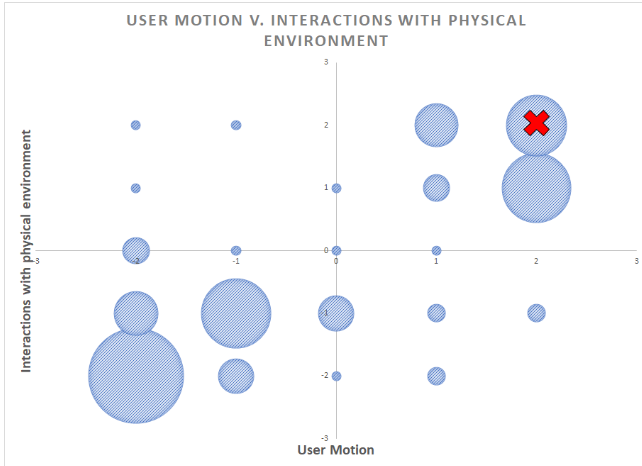

Figure 3: Distribution of papers based on user motion and interaction with the physical environment.

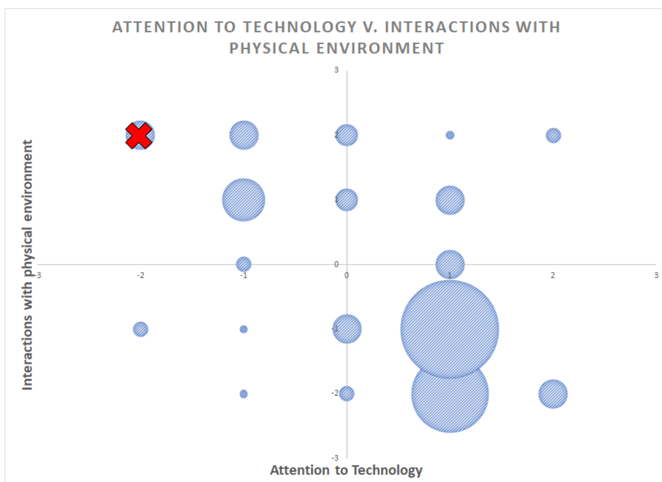

Figure 4: Distribution of papers based on attention to technology and interaction with the physical environment.

A consistent theme in our investigation of the literature is that one of the areas that is understudied is that of technologies to support face-to-face activities where children primarily pay attention to things other than technology including other children, the physical environment, and adult facilitators, and where they are free to move around as they would in traditional play settings. *StoryCarnival* fits within this understudied category of technology supporting a type of activity for which there is ample empirical evidence of benefits for preschool children: ToM-style play.

3 *STORYCARNIVAL* DEVELOPMENT AND DESCRIPTION

StoryCarnival was designed to make it easier to implement ToM-style play. Pantoja et al. designed *StoryCarnival* over 39 sessions working with two groups of 3-4-year-old children at a preschool [27]. During these sessions researchers identified areas that made ToM-style play difficult to implement and added technology supports for these [27]. *StoryCarnival* has three components: e-book-style stories that introduce play themes and characters of equal importance on which to base play; a play-planning tool; and a Tangible, Authorable Voice Agent (TAVA) to engage the children during play [27].

3.1 Stories

ToM-style play requires all participating children to have a common understanding of a story on which to base play [29]. This common understanding helps children establish common goals and facilitates communication among children [56–58]. Stories in children's media 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). 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.

The stories are 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 [59]. 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 approach is intended to encourage children to develop their own resolution for each story through role-play. See Figure 5 for screenshots of the Space Explorers story.

Figure 5: Screenshots from the Space Explorers story.

3.2 Play Planning

The StoryCarnival developers also noted that planning play could be difficult because children did not always remember the traits of story characters [27]. The play planner part of the StoryCarnival app shows a story's characters from which to select, and upon selection reminds children of the selected character's skills and role in the story. The play planner also uses Amazon Polly's speech synthesizer to generate character speech. See Figure 6 for screenshots.

Figure 6: Screenshots from the play planner corresponding to the Space Explorers story showing the initial screen and the screen shown when Horse is selected.

3.3 Keeping Children Engaged Through Tangible, Authorable 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 [27]. While facilitator intervention is an option in these situations, they wanted to provide support through technology in a way that would complement 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: 1.) children acted as mediators of the voice agents, asking other children, for example, to help the voice agent with a request; 2.) voice agents promoted social interactions with peers; and, 3.) voice agents could redirect children's behavior to re-engage with play [27]. 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 [27].

In this work, we used a voice agent called 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 7). The researchers controlling MiniBird could type text in an app that would produce speech through the Bluetooth speaker using the Amazon Polly speech synthesizer. MiniBird was therefore a Tangible, Authorable Voice Agent (TAVA), in that it was controlled by adult facilitators rather than being automated.

Figure 7: The MiniBird voice agent.

4 COMPARING SOCIODRAMATIC PLAY WITH AND WITHOUT STORYCARNIVAL

4.1 Research goal

The goal of the study presented in this section of the article was to understand how the technology supports provided by *StoryCarnival* change sociodramatic play when compared to ToM-style play without technology supports. A prior publication focuses on an analysis of how sociodramatic play changed for shy children [60]. In the analysis presented in this article, we focus on signs of children's play maturity [29], as presented in the introduction, such as children's social coordination, the role of adult facilitators including their use of the TAVA, children's interactions with the TAVA, and the influence of *StoryCarnival's* stories on play.

4.2 Methods

4.2.1 Participants

After obtaining approval from our University's Institutional Review Board, we recruited five 3-year-old children (3 girls, 2 boys, age 42-45 months at the beginning of the study) and twelve 4-5-year-old children (6 girls, 6 boys, age 50-65 months at the beginning of the study) from a preschool in a city with a population of about 100,000 in the United States by sending recruitment packages to participants' parents through their teachers. The preschool is located in a census tract identified as a low-income community. We obtained informed consent from parents, and children could interrupt their participation at any time if they wanted to stop playing. Parents indicated that four 3-year-olds and seven 4-5-year-olds used tablets 10-60 minutes per day, primarily to use video streaming and educational apps. Parents also indicated that one 3-year-old and two

4-5-year-olds used voice assistants for 1-15 minutes per day to play music and check the weather forecast. While we did not ask parents about languages spoken at home, all participating children appeared to have native English language fluency. We also did not ask about developmental delays, but none were brought to our attention by parents, teachers, or children.

4.2.2 Design

We conducted the study over eight weeklong phases in which children engaged in ToM-style play. During half the sessions, they did so with no technology supports (A phases), while during the other half they did so supported by *StoryCarnival* (B phases). All children when through phases in the same order, which was assigned at random (order: A, B, B, A, B, A, A, B), and children participated in two sessions during each phase (see Table 2). 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.

4.2.3 Materials and Procedure

We conducted all sessions at the participants' school between October and December of 2019, just before parents picked up their children, at the teachers' suggestion. 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 (e.g., 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 (no-tech) phases, we used stories from the *Detective Dinosaur* series, which we identified as both appropriate for the age group and for ToM-style play with the help of three children's librarians. The specific stories we used were: "The Case of the Missing Hat" and "Night Patrol" from *Detective Dinosaur* [61], "Lost" and "Found" from *Detective Dinosaur Lost and Found* [62], and "Under the Weather" from *Detective Dinosaur Undercover* [63]. During B (*StoryCarnival*) phases, we showed children stories through the *StoryCarnival* app using an iPad (4th generation): "Party," "Castle in the Woods," "Castaways" (two parts), and "Space Explorers" (two parts). The researcher delivering the story to the children also asked questions (e.g., "What do you think will happen next?" or "How do you think [a character] is feeling?") to emphasize the content of the story. Regardless of the phase, the story-experiencing portion of the activity lasted about five minutes.

After experiencing a story, the 3-year-old children 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. During the first two phases (one A and one B phase) the 4-5-year-old group split into two groups of six, each supported by two researchers. 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 [27].

The children then selected characters to play, prompted by a researcher. During A (no-tech) 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 (*StoryCarnival*) 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 (no-tech) 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 (*StoryCarnival*) phases, if there were two researchers available, one played the same role researchers played in A (no-tech) phases, while the other one controlled the speech of the voice agent, MiniBird. If only one researcher was available, they played a hybrid role of interacting directly with children while also controlling MiniBird.

Week	1		2		3		4		5		6		7		8	
3yo	A	A	B	B	B	B	A	A	B	B	A	A	A	A	B	B
4-5yo	A*	A*	B*	B*	B	B	A	A	B	B	A	A	A	A	B	B

Table 2. Sessions for each group of children by week. A sessions did not involve technology while B sessions were supported by *StoryCarnival*. During the first four sessions (marked by *) 4–5-year-old children split into two groups, while during the remaining sessions they split into three groups.

4.2.4 Data Analysis

We conducted three types of content analysis of the video recordings: a conventional approach in which we categorized open-ended observations, a summative approach in which we quantitatively analyzed transcripts, and a directed approach in which we coded for specific behaviors targeted by ToM [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. At least two of these researchers watched each video. The researchers independently wrote open-ended observations on 894 sticky notes and organized them in an affinity diagram to extract themes using Lucidchart [64] over the course of several meetings. 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) in Table A.1. 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 (e.g., 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 to the ToM goal of children speaking to each other as they play [29] (p. 151).

For the directed approach, two coders used BORIS [65] to code specific behaviors observed in 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 [29]), number of distinct symbolic uses of props, and for B (*StoryCarnival*) phases, the amount of time children spent physically engaged with the voice agent (e.g., 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, η^2_p for effect size where .0099, .0588, and .1379 are used as benchmarks for small, medium, and large effects [66]) and otherwise used Friedman's test (we report medians, χ^2, and p values, as well as Kendall's w for effect size [67]). 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.

4.3 RESULTS

In previously published work, we reported our findings that children were more likely to be on-task (e.g., engaged in an activity related to the group's play) during *StoryCarnival* (B) sessions than no-tech (A) sessions, children were more verbally engaged overall in B (*StoryCarnival*) sessions than A (no-tech) sessions, and that these differences appeared to be mainly due to MiniBird giving shy children the motivation and confidence needed to engage their peers in play, making participation in the *StoryCarnival* sessions more equal [60]. There were also no statistically significant differences in the symbolic use of props during play. In this work, we aim to describe differences in children's play at the group level with and without the *StoryCarnival* supports in more detail, elaborate on patterns we observed in children's interactions with MiniBird, and outline outstanding implementation challenges. Open-ended qualitative observations are linked to the sessions in which they were observed in Appendix B.

In the sections below, we discuss in detail aspects of play directly related to play maturity as explained in the introduction, and the impact of *StoryCarnival* components on these. We discuss coordinated versus parallel play, facilitator interactions, voice agent interactions, the impact of different types of stories on play, and challenges we faced during the activities.

4.3.1 Coordinated vs. Parallel Play

As we mentioned in the introduction, coordinated play is both an important characteristic of sociodramatic play [68] and a specific goal for *ToM*-style play [29], while parallel play is a step below in terms of play quality [29,68]. Through our conventional content analysis, a key finding was that children in the 3-year-old group were more likely to coordinate play during B (*StoryCarnival*) than A (no-tech) sessions, but that coordination characteristics were similar across sessions for the 4-5-year-old group.

More specifically, we found that children in the 3-year-old group were slow to engage with one another directly in the first few A (no-tech) sessions. They played in parallel during A (no-tech) sessions throughout the study but appeared to coordinate their play during one A (no-tech) session in early December, responding to one another's actions and ideas seamlessly. We observed this type of coordinated play between the 3-year-olds more often during B (*StoryCarnival*) sessions. Following is an example of this type of coordinated play from session 3B04, with support from an adult facilitator (R1):

Phyllis (walking around to pick up hats): And birthday hats.

Pam: I need one.
R1: You need one, Cat? Do you want this one?
(Pam puts on the hat.)
R1: Does everyone need one?
Jim (pretending to drive a car): Vroom vroom not me!
R1: You're going too fast, right?
Jim: Vroom vroom vroom!
(Phyllis puts on a hat and gives one to Lucas.)
R1: Do we need anything else from the store? Oh! I don't think we have balloons yet -- can you get us balloons?
(Jim pretends to drive to the store and Phyllis gives R1 a hat, which R1 puts on.)
R1: Thank you! I'm all ready for the party now.
Jim: Vroom vroom! I got a lot of balloons.

The 4-5-year-olds' play was less coordinated than the 3-year-olds' play in both types of sessions. Parallel play between the 4-5-year-olds appeared variable depending on the social dynamics of specific groups, regardless of condition. Some children appeared to particularly dislike playing with certain others, and children occasionally split off to play with one or two group members independently of the other group members. In these cases, they had coordination with one or two other children, but not with the entire group. The 4-5-year-olds appeared to play most collaboratively when they were focused on building something from a story. While we observed this behavior in both A (no-tech) and B (*StoryCarnival*) sessions, it was an especially interesting observation because multiple *StoryCarnival* stories specifically reference characters building or fixing items. In line with this, the 3-year-olds used props for building more often in B (*StoryCarnival*) sessions than in A (no-tech) sessions.

4.3.2 Facilitator Interactions

Adult facilitators can play important roles in supporting sociodramatic play, with the goal of transitioning children to more independent, mature play, as recommended by researchers behind ToM [29]. In other words, adult facilitators should provide assistance when needed while avoiding taking "too much of the lead in play" [29].

Our conventional content analysis provides details on how facilitators participated during each type of session. The general finding was that they had to take a more central role during A (no-tech) sessions than during B (*StoryCarnival*) sessions when children played more independently. In addition, facilitators played somewhat different roles in the two types of sessions mainly due to differences in the types of stories used to motivate play and the use of MiniBird.

During A (no-tech) sessions, facilitators played specific characters from the *Detective Dinosaur* stories, often to fill a role no child picked. In the 3-year-old A (no-tech) sessions, one facilitator often focused on encouraging a shy child to engage in play and the facilitators managed conflicts that arose when children had trouble sharing. In the 4-5-year-old A (no-tech) sessions, the facilitators prompted children to rejoin play when they were distracted and guided them when they finished replaying a story, coming up with variations for the stories to keep the children interested.

During B (*StoryCarnival*) sessions, facilitators had similar interactions with children, although they were less likely to play specific characters in the *StoryCarnival* stories, and the 4-5-year-olds' teacher intervened occasionally to manage behavior in the one-facilitator groups. However, facilitators did have additional MiniBird-specific interactions in B (*StoryCarnival*) sessions. For the 3-year-old group, the facilitator who was not controlling MiniBird would repeat what MiniBird said if children could not hear it and reinforced MiniBird's suggestions (22.8% of facilitator lines mentioned

MiniBird). Facilitators also had to repeat MiniBird in the 4-5-year-old sessions and had to manage issues that arose when children tried to play rough with MiniBird or had trouble sharing MiniBird (19.2% of facilitator lines mentioned MiniBird). As shown in Figure 8, MiniBird spoke less often than facilitators did and in our conventional content analysis we noted that facilitators focused on controlling MiniBird spoke less often.

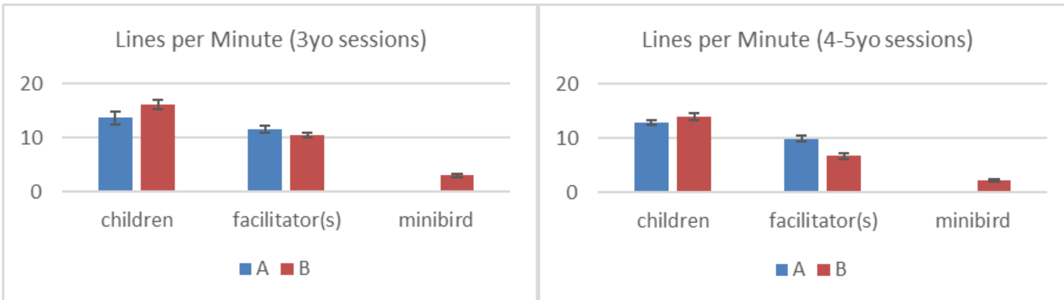

Figure 8: Lines per minute for 3-year-old sessions on the left and 4-5-year-old sessions on the right. Bars correspond to mean values and error bars are two standard errors long. To calculate children values, all lines spoken by children during A (no-tech) session were added and divided by the length of the session. Similarly, if multiple facilitators were in A (no-tech) session, all their lines were added, then divided by the length of the session.

Here we present an example of a facilitator playing a central role and attempting to move a story along in session 4A08x:

Bruce (using a block as a phone): Hello.
R1 (picking up another block): Hello! I hear you!
Boo: Hello!
R1: Hello, Detective Dinosaur! What's going on?
Bruce: I lost my hat.
R1: You lost your hat? Oh no! Where should we go to find it?
Boo: Um, you should get a new hat at the store!
R1: At the store? Yeah! Ricky Raptor might sell hats at the store. You want to try there?
Bruce: Yeah.
Eeyore: Yeah, you should get a new hat.
Bruce: Yeah, I know.
R1: Okay. Bye! (hangs up the phone)

Here we present an example of the children directing play more independently in session 4B06z:

(Dora suggests throwing a "stinky party" instead of a birthday party.)
Pooh: I can dump stinky spray on you, MiniBird.
R3: Is MiniBird stinky now?
Pooh & Sonic: Yeah.
Pooh: This is a stinky party.
Kanga: Stinky spray.

Sonic: The bird is stinky.
Pooh: I'm going to stink.
R3: I know, I am too.
Dora: Not me!
R3: Not you? How come you're not?
Pooh: Because I put water in the air.

These differences were also reflected in session transcripts. For example, in 4-5-year-old sessions, facilitators spoke more words per minute during A (no-tech) sessions than facilitators and MiniBird spoke combined during B (*StoryCarnival*) sessions (see Table 3). For both age groups, facilitators spoke significantly more lines before children responded during A (no-tech) sessions than B (*StoryCarnival*) sessions (see Figure 9 and Table 4). These repeated lines by facilitators suggest both greater involvement by facilitators as well as some difficulties engaging children during A (no-tech) sessions.

Measure	Age	Mean/Median A (no-tech)	Mean/Median B (*StoryCarnival*)	Stat	p-value	Effect size
Words/minute	4-5	79.54	63.93	X^2=6.545	.011	Kendall's W = .298

Table 3: Comparisons between facilitators' behavior under the two conditions.

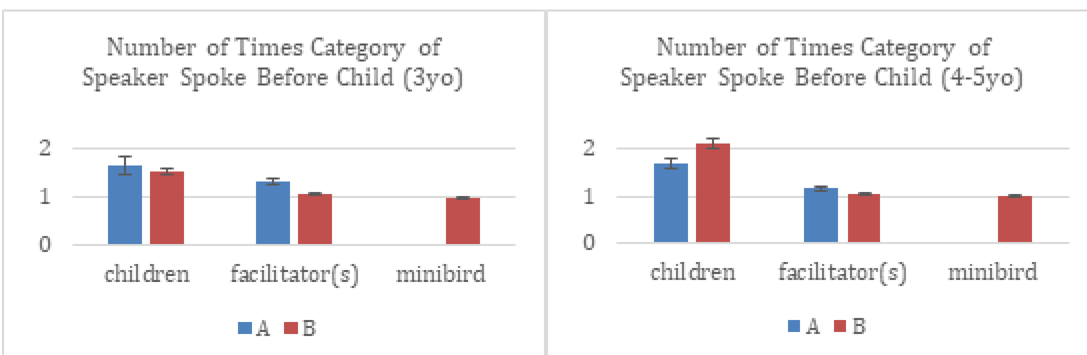

Figure 9: Number of lines a category of speaker spoke before a child spoke. Bars show mean values and error bars are two standard errors long. Data for 3-year-old sessions is on the left, for 4-5-year-old sessions on the right.

Measure	Age	Mean/Median A	Mean/Median B	Stat	p-value	Effect size
Child speaking after another child/minute	4-5	4.432 (SD=1.657)	6.584 (SD=2.150)	F(1,21)=13.33	.001	η^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
Lines by facilitator before child speaks	3	1.334 (SD=.1452)	1.065 (SD=.0366)	F(1,7)=31.889	.001	η^2_p = .820
Lines by facilitator before child speaks	4-5	1.119	1.031	X^2=6.545	.011	Kendall's W = .298

Table 4: Comparisons between children's behavior under the two conditions.

The centrality of facilitators to play during A (no-tech) sessions is also reflected in 4-5-year-old children being more likely to speak after a facilitator than another child in A (no-tech) sessions, even though children spoke more often than facilitators (this is possible through interactions where, for example, a facilitator speaks first, one child responds to the facilitator, the facilitator responds, and then two children speak in a row). More specifically, 4-5-year-old children cumulatively spoke significantly more lines per minute after facilitators than after other children during A (no-tech) sessions, but this was not the case for B (*StoryCarnival*) sessions (see Figure 10 and Table 5). These results also suggest that 4-5-year-old children engaged with their peers somewhat more independently in B (*StoryCarnival*) sessions than in A (no-tech) sessions. While 3-year-old children cumulatively spoke significantly more lines per minute after facilitators than after other children during A (no-tech) sessions, this was also true for B (*StoryCarnival*) sessions (see Table 5).

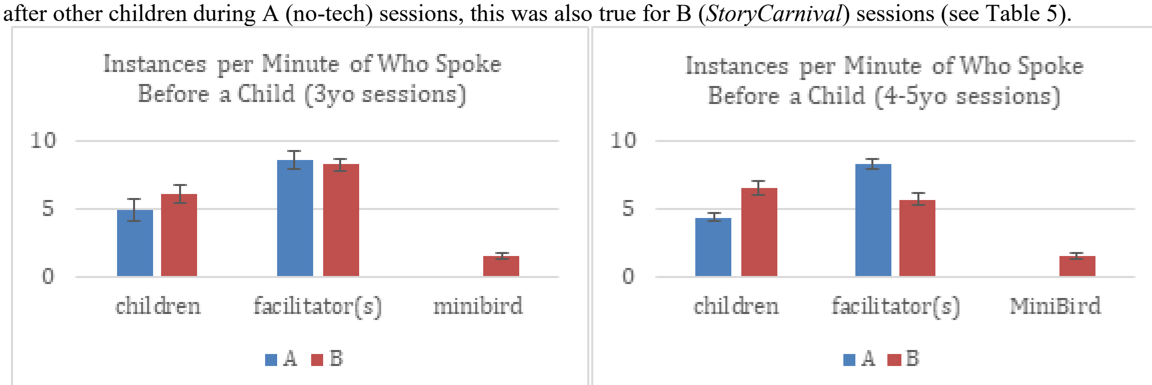

Figure 10: Instances per minute of what category of speaker spoke before a child. On the left, bars show mean values for 3-year-old sessions, and on the right for 4-5-year-old sessions. Error bars are two standard errors long.

Measure	Age	Phase	Child mean	Facilitator + MiniBird mean	F	p-value	Effect size

Responses/minute	3	A	4.917 (SD=2.316)	8.694 (SD=1.789)	$F(1, 7)=18.246$	.004	$\eta^2_p = .723$
Responses/minute	3	B	6.166 (SD=1.832)	9.922 (SD=1.149)	$F(1, 7)=50.124$	<.001	$\eta^2_p = .877$
Responses/minute	4-5	A	4.432 (SD=1.656)	8.367 (SD=1.488)	$F(1,21)=84.227$	<.001	$\eta^2_p = .800$

Table 5: Comparisons between children and facilitators (and MiniBird for B (*StoryCarnival*) sessions) within a particular condition.

4.3.3 Voice Agent Interactions

The purpose of the MiniBird TAVA was to enable adult facilitators to have another line of communication and interaction with children to help support ToM-style play. In this study, during B (*StoryCarnival*) sessions, facilitators were responsible for controlling MiniBird. Control of MiniBird required use of a laptop to type what MiniBird would say. The task load involved in making MiniBird speak had an impact on how often MiniBird spoke, making its verbal interactions with children much less frequent than those children had with other children or facilitators (see Figure 10). Despite its small share of verbal exchanges, MiniBird played a role in incorporating children into play as evidenced by the correlation between mentions of MiniBird and children's lines and words spoken discussed in previous work [60]. The level of attention children paid to MiniBird is illustrated through the fact that children quickly responded when MiniBird spoke, even if they had to ask what MiniBird said (see Figure 9). Based on our directed content analysis, during B (*StoryCarnival*) sessions, 3-year-old children spent 20% and 4-5-year-old children 17% of session time physically interacting with MiniBird (e.g., holding or putting props on the agent). In the following sections, we provide details on how children interacted with MiniBird based on our conventional content analysis.

4.3.3.1 MiniBird's Communication with Children

In the 3-year-old sessions, adult facilitators used MiniBird to make suggestions to move the story forward and redirect children when their play drifted away from the story context. MiniBird also repeated and reinforced suggestions the children made and encouraged the children to share. In the 4-5-year-old sessions, MiniBird attempted to help children coordinate play by making suggestions to move play along, reminding children of story tasks, and encouraging children to work together. The children laughed when MiniBird made jokes but could get distracted trying to convince MiniBird to say something specific. The 4-5-year-olds seemed to expect MiniBird to behave almost like a friend would and seemed disappointed when it failed to meet those expectations. Because there were two to three groups of 4-5-year-olds in one room, children had some trouble hearing MiniBird and MiniBird occasionally had to repeat itself at children's request. Some of the 4-5-year-olds tried to whisper to MiniBird and the facilitator controlling MiniBird could not hear what the children said and respond appropriately. If MiniBird did not respond to a child quickly enough, the children tended to get frustrated with MiniBird.

4.3.3.2 Wanting to Interact with MiniBird

The 3-year-olds were initially shy when first interacting with MiniBird but showed interest in talking to MiniBird after some hesitation. They asked for turns holding and talking to MiniBird, quieted down when MiniBird was speaking, and sometimes insisted on hearing MiniBird repeat itself rather than having the facilitator repeat what MiniBird said if they missed it. They sometimes took on the role of repeating what MiniBird said to make sure everyone heard it. The children also responded quickly and positively to MiniBird's suggestions and often wanted to show things they built to MiniBird.

In the last 3-year-old session, the children directed their attention to MiniBird even when they were not directly interacting with it.

The 4-5-year-olds were initially interested in the novelty of MiniBird, and an interest in MiniBird occasionally brought a group of children together. One group specifically made sure to bring MiniBird along when they were exploring a new area. Like the 3-year-olds, the 4-5-year-olds often wanted to show MiniBird the things they built, responded to MiniBird's suggestions, repeated what MiniBird said, asked MiniBird for opinions, and continued to direct attention to MiniBird at times the facilitator was not actively controlling MiniBird. However, the 4-5-year-olds tended to want more exclusive access to MiniBird and would take it away from the group to try to talk to it one-on-one. The 4-5-year-olds responded positively when MiniBird gave them personal attention.

4.3.3.3 Caring for MiniBird

The 3-year-old group centered their play around caring for MiniBird's needs during multiple sessions. In one session, they "adopted" it as the other characters' "baby" and roleplayed as parents. On other occasions they held it tightly to keep it safe during scary parts of the story, fed it, bathed it, and covered it to keep it dry during a "rainstorm". They speculated about how MiniBird felt (e.g., "He might be hungry,") and expressed concern about how it was doing. They built things based on MiniBird's perceived needs (e.g., they built a bed if they thought MiniBird might be sleepy). Near the end of the study, a couple of the 3-year-old children expressed interest in how MiniBird worked, asking why it talks.

The 4-5-year-olds centered their play around MiniBird in early B (*StoryCarnival*) sessions and some in later sessions with two facilitators. They self-regulated sharing MiniBird and some children seemed to largely ignore MiniBird, especially if they were engaged in some other aspect of play. Some 4-5-year-olds expressed an interest in how MiniBird worked in the first few sessions, asking if it could do various things by itself and how it was able to speak. They asked MiniBird personal questions about its interests and allergies it might have. Rather than speculating about how MiniBird felt, the 4-5-year-olds tended to ask it directly. When MiniBird expressed a need, the children responded by gathering items to help or incorporating MiniBird into structures they had already built.

4.3.3.4 Affection for MiniBird

In addition to the active care the children showed MiniBird, they also often expressed affection for MiniBird. The 3-year-olds were initially somewhat in awe of MiniBird and giggled the first times it spoke or introduced itself (and when a facilitator made it "dance"). One child said, "I love you, MiniBird," directly to it during the first session. At the end of the first session, the 3-year-olds did not want to give MiniBird back to the facilitators. While this initial excitement faded over time, the children still held, hugged, kissed, smiled at, and jumped with excitement at MiniBird throughout the study. The 4-5-year-olds were also excited to meet and introduce themselves to MiniBird as their characters in early sessions. They were less affectionate with MiniBird than the 3-year-olds were but still smiled and giggled when they were allowed to hold MiniBird or when MiniBird spoke directly to them. The affection and care that children demonstrated toward MiniBird showed that MiniBird influenced the children, but this influence required minimal prompting from MiniBird itself.

4.3.3.5 Aggression toward MiniBird

A few of the 4-5-year-olds showed signs of aggression toward MiniBird. They handled it roughly, especially when they had to give it up to someone else. They hit, dropped, or threw things at MiniBird and laughed if it said, "ouch," in response. One boy suggested cutting MiniBird in half during one session. At least some of this aggressive behavior could have stemmed from frustration when MiniBird did not respond quickly or personally enough to a specific child. We also observed children playing with other props aggressively during both types of sessions.

4.3.4 Story-Related Observations

There were no substantial differences in the children's initial reactions to or experiences of the stories between A (no-tech) and B (*StoryCarnival*) sessions (e.g., while listening to stories from a book or app). Below, we discuss other story-related observations based on our conventional content analysis.

4.3.4.1 Character Selection Observations

The 3-year-old group exhibited some trouble remembering characters from the Detective Dinosaur stories during character selection and had an easier time selecting roles with *StoryCarnival's* play planner. The 4-5-year-olds were quicker at selecting characters in both types of sessions than the 3-year-olds were. A couple of 4-5-year-old children refused to pick a character during most A (no-tech) sessions and wanted to build instead or play as characters from other media. In one A (no-tech) session, one of these children decided to play as the lid of a trash can which made a clanging sound in the story. These children would usually select a role during B (*StoryCarnival*) sessions based on the type of activity the character was primarily responsible for (e.g., if they wanted to build, they would pick the character that built a shelter in the story), even if they showed some initial resistance to picking a character. Another 4-5-year-old always wanted to play a cat, which happened to work out in B (*StoryCarnival*) sessions as there was always a cat character in *StoryCarnival* stories, but there was a cat in only one Detective Dinosaur story.

4.3.4.2 Replaying versus Continuing Stories

The main difference between A and B (*StoryCarnival*) sessions with respect to how play started was that during A (no-tech) sessions children would typically begin by recreating at least part of the story they listened to, while during B (*StoryCarnival*) sessions they would pick up where the story left off. In early A (no-tech) sessions, the 3-year-olds expressed excitement about replaying the *Detective Dinosaur* stories and spent the whole session replaying a story. In later A (no-tech) sessions, they largely discarded the storylines and instead wanted to skip to their favorite parts of the story or play within the general story theme or characters without following the plot of the story. In an early A (no-tech) session, the 4-5-year-olds expressed initial excitement about replaying the story as the story characters, but over the course of the study frequently requested to change roles midway through A (no-tech) session. This was most common when a child was waiting for the next time their character appeared in the story or got bored of their role. In these scenarios, children asked to play as puppies, kitties, baby dinosaurs, superheroes, and characters from the Mario franchise. The 4-5-year-olds rushed through story replay in A (no-tech) sessions, skipping over story details and finishing replay halfway through the session time. Sometimes the 4-5-year-olds never finished replaying the story. Other times they replayed the story multiple times in A (no-tech) session or blended the story with another *Detective Dinosaur* story.

Children did not always know what to do after they finished replaying a *Detective Dinosaur* story and relied on suggestions from facilitators during these transitions. They either switched to replaying a different *Detective Dinosaur* or *StoryCarnival* story or extended the original story, keeping certain story elements (e.g., finding a cat) and taking the story in a new direction (e.g., building a house for the found cat).

In the first B (*StoryCarnival*) session, the 3-year-olds played within the setting of the story but without much relationship to the plot of the story. In subsequent B (*StoryCarnival*) sessions, the 3-year-olds tended to pick up play from the end of the story and extend the plot as their characters. The 4-5-year-olds approached the *StoryCarnival* stories similarly to the 3-year-olds: picking up from the end of the story and extending it in a creative direction. In later B (*StoryCarnival*) sessions, the 4-5-year-olds were especially quick to execute their roles and began working on story-related tasks without any prompting from facilitators. In B (*StoryCarnival*) sessions, the 3-year-olds never switched to a different story and always stayed in the general context of the original story. They had ideas for how to extend the *StoryCarnival* stories (e.g., if a character built a boat in a story, the children could extend the story by sailing in the boat). The 4-5-year-olds switched to different stories less often in B (*StoryCarnival*) sessions than A (no-tech) session and were more likely to continue extending the stories than they were in A (no-tech) sessions with less guidance from facilitators. Role switching also happened in 4-5-year-old B (*StoryCarnival*) sessions, but less frequently than during A (no-tech) sessions. Children in all groups suggested making small changes to stories' plots and incorporated concepts from other stories, class, home, and other media in both A (no-tech) and B (*StoryCarnival*) sessions.

4.3.5 Challenges

4.3.5.1 Behavioral

Children's challenging behavior was similar across A (no-tech) and B (*StoryCarnival*) sessions. For the 3-year-old group, the most common struggle was sharing props, and in B (*StoryCarnival*) sessions the added difficulty of sharing MiniBird. There was also some destructive behavior, mostly knocking down another child's prop-built constructions, motivated by attention-seeking. The 4-5-year-old children displayed destructive behavior similar to that of the 3-year-old children, but more often and with the addition of throwing props, also seeking attention. With 4-5-year-old children we observed fewer issues with sharing props than we did with 3-year-old children, as well as fewer challenges sharing MiniBird.

4.3.5.2 Noise and Distractions

The 4-5-year-old children participated in sociodramatic play in two or three separate groups simultaneously in a large room as explained in Section 4.2.3. This setup, which could occur in any classroom attempting to implement ToM-style play, brought about two challenges. The first was that the noise level tended to be higher, which made it more difficult for the facilitator to understand children, and sometimes for children to hear MiniBird, as discussed in Section 4.3.3.1. Having the children's teacher present alleviated some noise issues. A less frequent problem was children becoming interested with what was happening in another group.

4.3.5.3 MiniBird Control in One-Facilitator Groups

When 4-5-year-old groups had one facilitator during B (*StoryCarnival*) sessions, we noticed that it was difficult for the facilitator to interact with children directly and control MiniBird at the same time. The user interface to control MiniBird was designed for a laptop computer, requiring the full attention of a facilitator. Therefore, facilitators in these groups had to decide at any given point whether to control MiniBird or engage directly with children.

4.4 DISCUSSION

4.4.1 StoryCarnival's Impact on Play Maturity

The educators behind ToM-style play provided contrasts between mature and immature sociodramatic play [29], which we listed in Table 1. If we consider these characteristics of mature play, the results presented above suggest that *StoryCarnival* may provide advantages with respect to characteristics (3) (play roles with specific characteristics instead of not playing within roles), (5) (coordinate play with multiple roles instead of engaging in parallel play), and (8) (can continue play from prior sessions instead of only being able to engage in play for 5-10 minutes), while not providing any disadvantages for any of the other characteristics.

With respect to (3), some children were more easily able to select characters from *StoryCarnival* than *Detective Dinosaur* stories and to continue play with these characters. Part of the reason may be that *StoryCarnival* stories made an emphasis on character traits, whereas *Detective Dinosaur* stories had stronger storylines with memorable events. Another factor, at least for 3-year-old children, was the play planner, which emphasized character traits once again.

With respect to (5) the better coordination of the 3-year-old group may have been due to the centrality of MiniBird during play. In our conventional content analysis, we observed that the 3-year-old group tended to keep MiniBird in a central location with respect to the rest of children, and children holding MiniBird typically wanted other children to know what MiniBird was saying. This common point of interest and reference, MiniBird, helped children coordinate their play. On the other hand, 4-5-year-old children were more likely to take MiniBird to the side, which did not decrease coordination when compared to A (no-tech) sessions, but did not help with play coordination as compared to the 3-year-old group. In a prior publication, MiniBird was also identified as a key contributor to engaging children who were not even engaging in parallel play, but just observing [26], which is typically a precursor to parallel play [68].

In terms of characteristic (8), we found evidence of children needing greater support for continuing play during A (no-tech) session than B (*StoryCarnival*) sessions, and to stay within the context of a single story. These differences may have to do both with the different types of stories used to motivate play and with the use of MiniBird during B (*StoryCarnival*) sessions to suggest story directions and things to do next.

4.4.2 TAVAs Augmenting Facilitator Capabilities

The sociodramatic play literature is clear on the importance of the role of adult facilitators during sociodramatic play [29,69–71]. Most of the roles these facilitators are called to play involve communicating with children. The importance of communication was reflected in the summative content analysis of transcripts, which showed high levels of adult facilitator verbal engagement throughout sessions. The addition of the MiniBird TAVA during B (*StoryCarnival*) sessions enabled facilitators to have another way of communicating with children through a character with which children could relate in a very different way (e.g., holding it and taking care of it). In a previous publication we provided evidence of facilitators using MiniBird to integrate children who otherwise had difficulty joining play [26]. In this paper's results we provide evidence of MiniBird's role in helping coordinate and extend children's sociodramatic play.

4.4.3 Impact of Stories Used to Motivate Play

The *StoryCarnival* approach to stories, introducing a story setting, characters with clear traits, and a situation to resolve, appears to be more novel than we expected. It fits between the use of stories with an ending from books to set up play [72] and the prompts used in improvisational theater [73]. Perhaps the closest approach is the use of simple scenarios in sociodrama to get participants to solve a problem through acting [74]. However, in sociodrama, the actors do not play make-believe characters in make-believe scenarios, there are typically no prepared stories but topics to address, and the goals of the activity are very different from those of sociodramatic play, including ToM [74].

While the approach to *StoryCarnival* stories could be achieved through non-electronic media (e.g., books), electronic versions provide the advantage of easy access to stories designed specifically to set up sociodramatic play. In addition, the latest version of *StoryCarnival* (developed after this study) includes story templates that can be used to generate a large number of distinct stories by enabling adult facilitators (with the optional input of children) to select story settings, characters, places, vehicles, food, and so forth.

4.4.4 *Implications for Child-Computer Interaction*

An implication of our research experience is that activities that consist mostly of interacting with other children and with non-electronic physical items can be positively influenced by technology that is not the primary focus of attention. Previous similar examples include research on supporting outdoor games (e.g., [75]) and outdoor spaces augmented with sensors and actuators (e.g., [76]). There is an opportunity to rethink similar activities to explore potential roles of interactive technologies to support desirable outcomes, while keeping the focus of the activities on connections with the social and physical environment.

We also found value in designing for the entirety of the activity, rather than one piece of it. *StoryCarnival* supports children and adult facilitators through motivating, planning, and implementing the activity. It also uses different technologies for different parts of the activity. Having well-integrated experiences that include support for all phases of an activity may make it more likely to happen as intended. Such support is likely to be particularly important for activities such as those described in the previous paragraph, where social aspects require group coordination and planning, and where technology is not the primary focus during the activity itself.

The research also highlighted opportunities for the use of TAVAs. By having them be controlled by adult facilitators, in contrast to commercial voice assistants, TAVAs are similar to puppets, except they are not physically connected to an adult, making it easier to incorporate them into play. Because they are controlled by adults they can provide a level of context-aware personal interaction with children that automated voice assistants do not come close to matching. Another advantage of TAVAs over voice assistants is that they do not need to collect data, therefore preserving the privacy of children and their families.

TAVAs may provide more approachable ways for interacting with some children, providing opportunities for better inclusion in preschools, for parents who find it difficult to communicate with their children, and for therapists treating children diagnosed with communication disorders. There could also be opportunities for children to control TAVAs, for example, enabling children with speech disorders to have a TAVA speak on their behalf.

The main research challenge for TAVAs is to minimize the cognitive load needed to control them. Since conducting this research, we have developed a touch-based user interface for controlling MiniBird, which we expect would work best if it minimizes any need to type. We also think it may work best if adult facilitators are able to control MiniBird from a wrist-strapped smartphone, such that both hands would remain free and there would not be a need to physically move to access the user interface. However, the best options for control may well be different for other contexts of use.

With respect to the design of our TAVA (MiniBird) it was clear that it supported greater buy-in among younger children [27]. It is not at all surprising that different characters will appeal to children of different ages and that individual children will change in their preference. Therefore, a recommendation for TAVA design would be to enable choices of agents. This recommendation is consistent with suggestions Hubbard et al. made based on their study of children's agency in child-agent interaction, in which they asked children to choose one of their stuffed animals to embody a conversational agent [77]. They could be designed such that visual artwork representing the character on the device could be changed, whereas it would be very easy to change the voice generated by the speech synthesizer. Such an ability to give children a choice of a TAVA that is associated with a character of interest could enhance the TAVA's effectiveness.

4.4.5 *Considerations for Pandemic Context*

Given the evidence outlined in the introduction on the negative impacts of the pandemic on children's socioemotional health, there is a need to consider extra supports for reintegrating children into social contexts and for them to feel comfortable playing, learning, and growing together with other children. There is likely a non-trivial number of children who may be joining preschools having never experienced regularly occurring interactions with other children their age. It is important that these children not feel excluded and that they feel comfortable joining social activities they can enjoy. Sociodramatic play appears ideal to re-integrate children because it builds social competencies and executive functions as outlined in the introduction. *StoryCarnival's* support for more coordinated, creative play is an added benefit. The child-computer interaction community should consider additional strategies to help re-integrate children socially and restore their socioemotional health and skills, giving parents and educators a broader toolset in a time of need.

4.4.6 Limitations

Our work is mainly limited by conducting our observations in one preschool with a small number of children (i.e., a small sample size). It is possible that results could have been different with other children in other preschools, in particular in areas socioeconomically and culturally different from the school where we conducted the research. However, our observations with respect to interactions with TAVAs are consistent with prior experiences with other preschool children [27,78]. The activities were also conducted by researchers as opposed to teachers. Future research should focus on the ability of teachers to use the system.

5 FUTURE WORK

We currently have three different paths in which we continuing research on *StoryCarnival*. First, we are exploring the use of *StoryCarnival* with neurodiverse children, both at home and in play groups run at a therapy center. Second, we are working on expanding support for teachers, trying to make the system as usable as possible, while supporting teachers in setting goals, planning sessions, and reflecting on outcomes. To support these two paths, we are making *StoryCarnival* publicly available at storycarnival.org. Third, we are planning to expand *StoryCarnival* to support other evidence-based practices with a focus on reducing children's social anxiety and promoting inclusive play.

Technology supports designed similarly to *StoryCarnival*, with stakeholders in a central role, have the potential to address current barriers to adoption of evidence-based practices in preschools [42] by incorporating teachers' points of view, not requiring teachers to attend training they may not be able to afford, fitting within currently accepted practices (e.g., having technology in a supporting rather than a central role), and keeping teachers in control. Using technologies with similar characteristics could help with the adoption of other evidence-based practices with older children as well.

6 CONCLUSION

The COVID-19 pandemic has greatly disrupted many children's lives, affecting their socioemotional health and development. We believe that technologies can play a role in re-integrating children and enhancing their socioemotional development by supporting evidence-based, creative, face-to-face social activities. We argue in particular for supporting activities where the focus is on other children and non-electronic objects, and where technology, in a secondary role, changes the dynamics of the activities in a beneficial manner.

In this article, we presented evidence that this particular approach to supporting children's face-to-face activities has not received much attention and present a mixed-methods evaluation of *StoryCarnival*, a set of technologies designed to support sociodramatic play in the style of the *Tools of the Mind* approach to early childhood education. We provided examples of how *StoryCarnival* changed the dynamics of children's sociodramatic play during our observations, leading to more mature play, including greater coordination, ability to stay in-role, and continuing play based on a story theme when compared to our observations of similar activities without *StoryCarnival*.

We hope our work inspires other researchers and practitioners to consider strategies to use technology to enhance children's face-to-face social activities while keeping the focus of the activities on connecting directly with others and with the physical world.

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APPENDIX A: SURVEY ARTICLES

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APPENDIX B

Observation	Sessions
Disengaged children engaging in play when given a turn with MiniBird	4B04x, 4B05z, 4B06z, 3B10, 3B15, 3B16
3-year-olds slow to engage with one another directly	3A01, 3A02
Parallel play	3A02, 3A07, 3A08, 3A12, 3A14, 3B15
Coordinated play	3A12, 3B04, 3B10, 3B15, 3B16
4-5-year-olds less coordinated than 3-year-olds	4A01y, 4A01x, 4B03y, 4B04y, 4B06x
Children splitting off from the group	4B04y, 4B05z, 4B06x, 4B06y, 4A08y, 4A12z
Coordinated play focused on building	4B06y, 4B09x, 4B09z, 4A11z, 4A12x, 4A12z, 4A14y, 4A14z, 4B16z
Building with props	3B03, 3B04, 3B05, 3B06, 3B09, 3B10, 3B15
Facilitators taking role of a character	3A07, 3A08, 4A08y, 4A08z, 3A11, 4A11y, 4A11z, 4A12y, 4A13y, 3A14, 4A14y, 4A14z
Facilitators trying to engage shy child	3A01, 3A08, 3A12
Facilitators managing sharing conflicts	3A12, 3A13, 3A14
Facilitators prompting children to rejoin play	4A01x, 4A02y, 4A07y, 4A12y
Facilitators guiding children after replay	4A01y, 4A08x, 4A08y, 4A12z
Teacher intervention to manage behavior	4B03y, 4B05y, 4B06x, 4B06y
Facilitators focused on controlling MiniBird less talkative	4B05x, 4B05y, 4B06x, 4B09y
MiniBird redirecting children	3B06, 3B09
MiniBird reinforcing children's ideas	3B04, 3B09, 3B10
MiniBird encouraging children to share	3B10, 3B15
MiniBird encouraging coordination	4B03x, 4B05z, 4B06x, 4B06y, 4B15x
Children distracted by MiniBird	4B06z
Children expecting MiniBird to behave like a friend	4B06z, 4B10y

Trouble hearing MiniBird, asking MiniBird to repeat self	3B05, 4B05y, 4B06y, 4B09z
Children whispering to MiniBird	4B09z, 4B09y, 4B10y, 4B16y
Frustration at slow MiniBird responses	4B06z, 4B10y
Early shyness around MiniBird	3B03
Asking for a turn with MiniBird	3B09, 3B15
Quieting down to listen to MiniBird	3B09
Repeating MiniBird	3B04, 3B05, 3B09, 3B10, 3B16, 4B03y, 4B05y, 4B05x, 4B09x
Quick response to MiniBird request	3B06, 3B15, 3B16, 4B03x, 4B05y, 4B10z, 4B15x, 4B15y
Showing MiniBird construction	3B03, 3B05, 3B09, 4B04x, 4B09z, 4B10y, 4B10z, 4B15z
Directing attention at MiniBird without direct interaction	3B16, 4B09x, 4B09y
Interest in novelty of MiniBird	4B03x, 4B03y
Interest in MiniBird bringing group together	4B03x, 4B09x
Bringing MiniBird to explore new area	4B09x
Asking MiniBird about opinions, interests, or allergies	4B04x, 4B05x, 4B05y, 4B05z
Positive response to individual attention from MiniBird	4B03x, 4B04x, 4B05z, 4B06z
Centering play around MiniBird	3B03, 3B04, 3B05, 4B03y, 3B09, 3B10, 3B15, 4B04y, 4B15z
Roleplay as MiniBird's parents	3B05
Protectively holding MiniBird	3B10
Feeding MiniBird	3B04, 3B15
Bathing MiniBird	3B15
Covering MiniBird to keep it dry	3B09
Speculating about how MiniBird felt	3B05, 3B06, 3B10
Expressing concern for MiniBird's feelings	3B06
Building for MiniBird	3B03, 3B05, 3B09
Asking about how MiniBird works	3B15, 4B03y, 4B04y, 4B09y
Self-regulating sharing of MiniBird	4B03y
Ignoring MiniBird	4B10z, 4B15x, 4B16y
Asking MiniBird how it feels	4B03x, 4B05y, 4B10x
Using objects to help MiniBird	4B03x, 4B05x, 4B09x, 4B09y, 4B09z, 4B10x, 4B10y, 4B10z, 4B15x, 4B15y, 4B15z, 4B16z
Giggling at MiniBird	3B03, 3B09, 4B03x, 4B03y, 4B04y, 4B05y, 4B06x, 4B06y, 4B06z, 4B09z
Expressing love for MiniBird	3B03
Resistance to returning MiniBird	3B03
Expressing excitement for MiniBird	3B03, 3B06, 3B09, 3B15, 3B16, 4B03x, 4B04x, 4B04y, 4B06x
Rough handling of MiniBird	4B03y, 4B04y, 4B06y

Aggression toward MiniBird	4B03y, 4B04y, 4B05y, 4B06y, 4B10z, 4B15x, 4B15z, 4B16z
Suggesting cutting MiniBird in half	4B06y
Trouble remembering characters	3A01, 3A11
Easy character selection	3B15
Refusing to pick a character	4A07y, 4A07z, 4A08x, 4A11z, 4A14x
Picking inanimate object as role	4A12z
Initial resistance to picking a role	4B09y
Excitement about playing characters	3A02, 4A01x
Discarding storyline	3B03, 3A07, 3A08, 3A11, 3A12, 3A13, 3A14
Asking to change role	4A01y, 4A02y, 4A08z, 4A11z, 4A13x, 4A13y, 4A14x, 4A14z, 4B15y, 4B16y
Rushing replay	4A13x, 4A13y, 4A13z
Never finishing replay	4A01x, 4A08z, 4A11z, 4A14y, 4A14z
Multiple replays	4A01y, 4A02x, 4A08x, 4A13y, 4A13z, 4A13x, 4A14y
Needing guidance after finishing replay	4A08y, 3A11
Switching to different story	4A02y, 4A07y, 4A07z, 3A08, 4A08x, 4A08y, 4A11y, 3A12, 4A13z, 3A14, 4A14y, 4B16z, 4B16y
Extending story	3B04, 3B05, 3B06, 3A07, 3B10, 3A11, 3A13, 3B15, 3B16, 4A07x, 4B09x, 4B09y, 4B09z, 4B10x, 4B10z, 4A11z, 4A12x, 4A12z, 4A13z, 4A14x, 4B15z, 4B16y, 4B16z
Starting play without prompting	4B09x, 4B10x, 4B15x, 4B15y, 4B15z, 4B16y
Trouble sharing props	3A07, 3A08, 3A12, 3A13, 3A14, 3B06, 3B10, 3B16, 4A02y, 4A11z, 4A11y, 4A13z, 4A14y, 4B05z, 4B15z, 4B15x, 4B15y, 4B16y
Trouble sharing MiniBird	3B03, 3B09, 3B10, 3B15, 3B16, 4B03y, 4B04y, 4B09z, 4B10y, 4B15z, 4B15x
Destructive behavior	3A02, 3A08, 3A11, 3A12, 3B03, 3B05, 3B06, 3B15, 4A01y, 4A01x, 4A02y, 4A07y, 4A08y, 4A08x, 4A11y, 4A11z, 4A12x, 4A13z, 4A14y, 4A14z, 4B05z, 4B06x, 4B06y, 4B10y, 4B10z, 4B15z, 4B15x, 4B16y
Interest in neighboring groups	4A07y, 4A08y, 4B06z, 4B06y, 4B06x
Facilitators struggling to interact with children while controlling MiniBird	4B05x, 4B05y, 4B06x, 4B09y

Table A.1: Observed behaviors coded during the conventional analysis along with session labels indicating the sessions during which each behavior was observed.