Authorable Virtual Peers for Autism Spectrum Disorders

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Abstract. In this paper we discuss the motivation and design of authorable virtual peers (AVP) for children with autism spectrum disorder (ASD). Children with ASD often lack the appropriate communication and reciprocal social interaction skills that lay the groundwork for school-based learning of literacy and for later academic and social achievement. Authorable virtual peers (AVPs) are language-enabled, 3D life-sized animated characters that look like children and are capable of interacting, sharing real toys and responding to children's input. As we describe in this paper, AVPs incorporate three interaction modes - interact, control and author - that scaffold three key interaction practices - rehearse, observe, and construct - as a way of helping children with ASD learn communication and social reciprocation skills. The design of AVPs is based on careful observation of collaborative storytelling in children with autism, and comparison with the same task in typically-developing children. This informs both our understanding of the disorder, and the specific skills an individual child can use the system to practice. AVPs extend the constructionist tradition in education - the use of technology as "objects to think with" - to learning about language and social interaction through building communicating virtual humans.

1 INTRODUCTION

Instructional technologies increasingly integrate a social as well as a cognitive component to help scaffold learning, and often these technologies use language to carry the social context. Thus, virtual peers [42], affective pedagogical agents [19] [26] [28] and interactive pedagogical dramas [44] use social language to create a context for learning. We know from the reports of parents, teachers, therapists and researchers (c.f. [23]), that many children with autism spectrum disorder (ASD) show an affinity for computers. However, the social and communication deficits of ASD make it difficult to engage in social interaction, and therefore access learning opportunities in these systems as well as in their classrooms and lives. In this paper, we propose to leverage the social and linguistic context that can be created by language-enabled instructional technologies to help children with ASD develop social and communication skills. In particular, we propose authorable virtual peers (AVPs) for children with ASD that enable children to tell stories with a life-sized, indefatigable virtual peer, as well as to control and author interactions for the virtual peer. AVPs extend the constructionist paradigm in instructional technology [22] to learning about language and social interaction through the construction of communicating virtual humans.

In what follows, we define autism spectrum disorder and describe the focus of our own research, on the deficits of reciprocal social interaction and social communication in children with ASD. We then described previous research in language-enabled ITS as well as in non-technological and technological interventions for children with ASD. We introduce authorable virtual peers as a way for children with autism to construct knowledge of reciprocal social interaction and social communication by interacting with and programming virtual peers. We then describe the design of virtual peers in terms of careful observation of children with ASD and comparison with typically-developing children, outline our coding scheme for observing children with ASD, and describe a pilot study that demonstrates the application of this coding scheme and how the results can be used in the design of AVPs.

2 WHAT IS AUTISM SPECTRUM DISORDER

Autism is a pervasive developmental disorder that affects a person's ability to communicate and interact with others. People with ASD experience difficulty in three main areas, known as the triad of impairments: reciprocal social interaction (for example, they may appear indifferent to other people), social communication (such as not understanding common gestures, facial expressions or affective responses), and imagination (difficulty developing interpersonal play and telling stories) [36]. Level of functioning varies greatly in children with ASD. Some children lack any functional language, while others may be able to express more than they can understand [8]. The difficulties with communication and reciprocal social interaction seen in autism and related disorders have been interpreted by some as reflecting an underlying deficit in theory of mind [4]. Theory of mind is the ability to understand that others have beliefs, desires and intentions that are different from one's own, and individuals with autism often demonstrate deficits in exactly this kind of understanding. The theory of mind deficit is an important theoretical perspective in research on ASD because it is uniquely able to explain this pattern of impairments [46].

Our focus in this research is to understand and diminish deficits in reciprocal social interaction and social communication in high-functioning children with ASD (children who are verbal with an IQ above 80) using an Authorable Virtual Peer (AVP). We address the triad of impairments that characterizes ASD by focusing our intervention on collaboration and narrative abilities through storytelling interaction with the virtual peer. We hypothesize that a collaborative narrative task with an indefatigable partner whom they themselves can program will enable individuals with ASD to practice turn-taking behaviors, taking on conversational roles, addressing the different beliefs of an interlocutor, and inventing narrative content. We focus on the ability to make oneself understood to another person, to use communication to achieve a common goal with another person, and the ability to behave in ways that demonstrate mutuality or joint work in conversation. These forms of social communication require skills that children with ASD can practice using an authorable virtual peer, such as gaining a listener's attention, initiating topics, maintaining

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topics and expressing ideas.

3 Background

AVPs draw motivation from previous work on language-enabled ITSs, non-technological social and narrative interventions for children with ASD, as well as previous research on technology solutions for ASD.

3.1 Language-enabled ITS

It is thought that being able to speak with ITSs (as opposed to type) results in increased believability and thus in higher motivation and increased ease of use [29]. Research on pedagogical agents, for example, aims to increase the believability of the tutor through the use of language, language-enabled behaviors, and para-verbal behaviors. Believability may include politeness behaviors [25], appropriate facial expression and expressive gestures [29], and cultural differences [34]. Our research on AVPs incorporates these findings into a virtual peer that not only employs language as the medium of communication between the system and the learner, but also enables children with autism to rehearse, observe and construct the communicative function of language, gesture and facial expressions.

In addition, natural language provides an ideal medium for eliciting knowledge construction [53]. Aleven and colleagues [2] created an ITS that engages students in natural language dialogue to state explanations of their problem solving steps in their own words. They evaluated the system on student's learning outcomes as well as their ability to provide better explanations. While learning outcomes were not different between the participants who interacted with the dialogue system versus participants who provided explanations through menus, students who received higher quality feedback from the system made greater progress in their development of quality explanations [2]. Likewise, the DIALOG project [6] uses a natural language tutorial dialogue system for evaluation of mathematical proof step utterances for soundness, granularity and relevance. Other techniques for eliciting knowledge construction in natural language dialogue include co-construction of explanations and directed lines of reasoning. We use AVPs to elicit knowledge construction by asking children to create natural language interactions for the virtual peer to perform.

A number of these projects focus on teaching mathematical or scientific concepts, such as LeActiveMath [30], CineSpeak (physics domain) [47], Geometry Explanation Tutor [2], DIAG (complex systems domain) [16], KSC-PaL (computer science domain) [15], DIALOG (mathematical proofs domain) [6], BEETLE (electricity and electronics domain) [53], etc. Our goal is to use advances in language-enabled technologies to teach language and communication itself - in this instance focusing on the reciprocal social interaction deficits of autism.

3.2 Social and Narrative Interventions for ASD

Non-technological approaches that target the social interaction deficits of ASD have existed for quite some time with fairly good results [17]. For reciprocal social interaction, approaches have included social groups, peer partnerships, formal social skills training programs, and narrative and/or pictorial approaches such as social stories or comic strip conversations.

Social groups target improvement in social skills such as perspective-taking, reciprocal interactions and listening skills, turn-taking during games and conversations, etc [17]. Social groups vary in how much structure they provide in social interaction, and sometimes involve typically-developing peers. Social groups are used with individuals with autism of all ages, including young children, adolescents and adults. Some groups are organized around a common interest, such as exploring computers, or may have a dual focus of providing a social event and discussing issues encountered by the participants related to their disorder [17].

Identifying "buddies" or "peer helpers" is another technique used to facilitate friendship and interaction skills in children with autism. Peer partners are typically-developing peers matched with a child with ASD and may fill a variety of roles such as peer tutor, project partner, extracurricular activity buddy, etc. Successful relationships are based on common interests and experiences. The peer is taught to understand autism and any predictable strategies used by the child with autism [17].

Social skills training programs such as the SCORE Skills [48], Skillstreaming [32] [33] and Social Effectiveness Training [24], explicitly teach social skills. The SCORE Skills Training Program focuses on a set of five skills that are needed for effective cooperative group work: "share ideas," "compliment others," "offer help or encouragement," "recommend changes nicely," and "exercise self-control." The skills are taught by asking participants to memorize the steps of each social skill and practice using the skills in role play situations. Similarly, Skillstreaming uses Structured Learning techniques of modeling, role playing, performance feedback and transfer of training, to teach children specific prosocial behaviors. Social Effectiveness Training uses five specific Teach Strategies to help children develop social skills: Positive Feedback, Ignore-Attend-Praise, the Teaching Interaction, the Direct Prompt, and Sit and Watch.

A common intervention employing narratives that model social competencies is the Social Story, developed by Carol Gray in 1991 [21]. A Social Story defines relevant cues in a social situation and describes appropriate responses. A small amount of recent research has provided empirical evidence on the effectiveness of social story interventions [1] [5]. Both these studies described case studies where social story intervention was effective for the situation target, and even transferred to other situations. Similarly, Comic Strip Conversations use simple drawings to represent a conversation between two or more people. By using stick-figure illustrations and text to represent speech and thought, the drawings illustrate an ongoing communication and help students improve their understanding and comprehension of conversation [20]. Social Skills Picture Stories, use digital pictures of actual children demonstrating various social skills [3]. The pictures are combined with text and cartoon bubbles to denote what the children are saying and thinking. Social Skills Picture Stories breakdown social skills, such as asking for help and initiating or joining conversations, into their components and make explicit what to say and do in social situations. Our own work can be seen as a technological solution to allow the child to participate as a character in a social story, and to also author behaviors for a kind of puppet in a Social Story interaction.

3.3 Existing Technology For Children with ASD

Technology-based interventions for ASD are typically designed for one of two different uses: some systems are created for indefinite use as an assistive tool, such as voice-output augmentative communication devices, while others are used as an instructional aid [18]. Our interest is this second category. Computer-assisted instruction for children with ASD focuses on the social mediating effect of technology, technologies for collaboration, and the ability of technologies to model social interaction.

Thus the Aurora project [13] has focused on building autonomous robots that can engage children in interactions which demonstrate important aspects of human-human interaction such as eye-gaze, turn-taking and imitation games. By slowly increasing the robot's behavior repertoire and the unpredictability of its actions and reactions, these researchers posit that the robot can be used to guide the child towards more 'complex' forms of interaction. Although the project is comparatively young, their findings include: 1. Children with autism do proactively approach robots [14]; and, 2. Robots can be used to elicit joint attention episodes between a child and an adult [40].

Virtual environments have proven to be another active area of research for social skill interventions. Kerr and colleagues [27] have designed a number of single user and collaborative virtual environments for adolescents and adults with Asperger Syndrome to teach social skills. They emphasize the importance of designing scaffolding into the system to guide users through the learning process. Similar research evaluates a desktop virtual environment for usability for people with autism [37]. This environment proved to be intuitive to adults with autism, who were able learn to use the equipment quickly. Interestingly, participants with autism who used the virtual world were more frequently judged as engaging in socially inappropriate behaviors, such as walking between two people speaking, even in the virtual world.

Bosseler and Massaro [7] evaluated the effectiveness of an animated cartoon agent vocabulary tutor for children with autism. The studies found that children with autism were able to learn new vocabulary words, retain much of the learned material over time, apply the words to new images, and apply the words outside of the computer program context. The study did not evaluate whether the children use the new vocabulary in spontaneous speech, which is a critical next step because highly structured training procedures that specifically control the environment may inadvertently confine these skills to such settings. Massaro's Baldi system has recently become a commercial product where an animated adult face gives feedback and motivates the child to continue working through exercises that include demonstrating understanding of stories that deal with social problems, sequencing of frames in stories, and practicing language skills [12]. The Center for Spoken Language Research at the University of Colorado [51] has also tested a literacy education system on children with autism. The system uses a cartoon face to give hints and explanations to children as they complete phonological awareness, reading, spelling and comprehension exercises. In each of these cases, an animated tutor motivates children, and gives them immediate feedback on their performance. However, neither project provides the peer context that appears to be so important to learning about social skills and literacy, nor do they provide a full-bodied animated agent that can allow children with autism to learn about the role of the body in social interaction. And, in both projects, content is authored by the teachers; there is no room for children to explore imagination by authoring their own stories - and to explore social reciprocity by authoring their own virtual peers.

4 AUTHORABLE VIRTUAL PEERS

A virtual peer is a life-sized, language-enabled, computer-generated, animated character that looks like a child and interacts with children by sharing real toys and responding to children's input [10]. Our original virtual peer (shown in Figure 1), developed to scaffold literacy skills, is named Sam. Sam interacts with children using speech and gestures modeled after the storytelling roles and turn-taking behaviors children use when interacting with each other [50]. The Sam virtual peer has two parts: the character and a toy castle and figurines. The character is an embodied conversational agent who is designed to look like a child around the age of 8. Sam was designed to be of ambiguous gender, and given an ambiguous name, such that each child could attribute his/her own gender to the character; pre-tests showed this to be the case (for ease of exposition, in this discussion Sam will be referred to as "she"). Sam is projected on a screen behind the toy castle, and is programmed to both attend to a child's stories and tell her own. Sam holds digital representations of the toy figurines, such that the toys can exist in either the physical world or on the screen. Children are instructed to put the toys into a "magic tower" in the castle to give the toys to Sam, and Sam puts the toys back into that tower so that the child can play with them.

Figure 1. Sam, the virtual peer

When a child arrives in front of the toy castle, Sam looks at the child, introduces herself and invites the child to tell stories with her. After the child greets Sam, Sam begins a story as she moves digital figurines around the castle, occasionally looking up to draw the child into the story. Sam's stories are designed so that Sam and the child can take turns to collaboratively construct a storyline. After beginning a story that defines a specific context (such as visiting a toy factory or building a tree house), Sam attempts to pass the turn to the child using children's turn-taking behaviors, such as paralanguage drawls ("she, umm.. then she...") and eye gaze towards the child. The child can then use the figurines in the magic tower to continue the story. While the child does so, Sam follows where the child is moving the figurine with head and eye movements, nodding, smiling, and prompting, "And then what happens?" or "Wow!" or "Cool."

Sam's stories demonstrate slightly more advanced decontextualized language (quoted speech, and enough temporal and spatial information for the audience to be able to reconstruct the temporal and spatial context of the story) than the target child is using. The hypothesis that guides this research is that by using language that is slightly more advanced than what the real child uses, that is within the real child's zone of proximal development (the distance children can perform beyond their current level in collaboration with others), Sam may encourage children to use these forms themselves [49]. In addition, because Sam is telling stories that demonstrate a different perspective on events than children's own, the narrative collaboration may engender the kind of cognitive conflict which, in turn, leads to cognitive restructuring and development [38]. In fact, evaluations of the Sam system support this hypothesis and demonstrate that as children interact with Sam over time, their use of decontextualized language increases [42] and their scores on the Test of Early Language Development (TELD) improve significantly [10].

4.1 Multi-modal Interface

To collaborate with children, our current Virtual Peer, Sam, uses eye-gaze, body and head posture, hand gestures, and speech to negotiate turns. In addition to exchanging turns, the interface is also responsible for acting out stories and for giving backchannel feedback during the child's stories. All of Sam's graphical and audio output is predefined. Each output command consists of a script defining the timings of speech and gesture actions. A female adult sound actor records all stories and utterances; the audio is then raised in pitch and slowed down so that it resembles that of a 6-year-old child. The gestures are based on observations of narrations by real children in the same context, and are meant to add to the realism of the experience, and reinforce events within the stories.

In our current implementation, gestures are created using 3D-character animation software (Poser). Character animations are exported from Poser as movie clips, and then imported into Macromedia Flash, a software platform that enables developers to create interactive, multi-media applications. The animations are then edited so that each body part can be controlled separately and subsequently assembled into fully articulated gestures. For example, Sam can be playing with a toy in her left hand, and, depending on the storytelling role she is assuming, she may want to look at the toy or at the child. The head and arm can be controlled separately in Flash and combined for the desired effect. To accomplish this, the animations are separated into body parts that are combined, "Mr. Potato Head"-style, at runtime. We edit each frame of the animation using Flash's graphics editing tools so that only the animated body part remains. Body parts are aggregated to paste together the target combination of gestures. A control engine, implemented in C-Sharp, parses scripts that specify specific playback times for audio clips and gestures. In addition, we use the C-Sharp engine to achieve intelligent behavior execution, for example, to automatically pair raised pitch in speech with raised eyebrows, to express emphasis.

We use a Wizard of Oz methodology to evaluate Sam, whereby an experimenter is controlling Sam with a complex interface while the child interacts with her. This interface can be used to select specific gestures, head movements, collaborative utterances (such as "Then what happens?" or "Is it my turn now?") and story segments.

While prerecorded speech and hand animated gestures provide the realism that may facilitate learning in language-enabled ITSs, it limits the flexibility of the system. Creating a new story for Sam currently requires a complex development pipeline of audio recording, hand animation, and script writing carefully timing speech and gestures.

4.2 Authoring Virtual Peers

In the new work described here, we hypothesize that we can leverage this technology in an innovative new direction to provide a context that can scaffold communication skills and reciprocal social interaction for children with ASD. This aim of the project has roots in research on intelligent tutoring systems [52], teachable agents [9], and natural language technologies employed in reading tutors [35] [43] [51]. However, the researchers from that tradition concentrate on instructing; the technologies are meant to teach content to children and not teach the form of interaction skills, and as such they are representations of adult-like tutors. That is, they are modeled on teachers (or the brains of more naive students, in the case of [9]) and not interactive peers and do not take advantage of the benefits of collaborative peer interaction demonstrated by our previous work [10]. In contrast, our virtual peer research is based on a model of social rapport and peer collaboration in narrative, which enables us to model the interactive behaviors and functions that the children are learning. We make use of a full-body conversational agent that can demonstrate the aspects of nonverbal behavior, and their functionality in the context of language, that children with ASD may have difficulty employing.

To enable children with ASD to not only interact with a virtual peer, but also *build* social skills, we are introducing a new kind of "authorable" virtual peer. The authorable virtual peer is used in three *interaction modes*. Children *interact* with the virtual peer by telling stories with the system. In a second mode, children also *control* the virtual peer by using a "Wizard of Oz" interface to select predefined responses. Finally, in the third mode, children *author* the virtual peer by using authoring tools to create new behaviors and responses. These interaction modes engage children in three *interaction practices* to help them develop communication and reciprocal social interaction skills (see Figure 2). By interacting with the virtual peer, children with ASD *rehearse* verbal and nonverbal interaction skills with an indefatigable peer. In control mode, children manipulate the verbal and nonverbal behaviors of the virtual peer and *observe* the effects on interaction. And by authoring virtual peers, children *construct* their own interaction examples. A number of systems exist that enable children to control avatars in a virtual world, such as Ghostwriter, a virtual role-play environment used as a preparation activity for writing stories [39]. However, these systems do not provide the fine-grain control over both verbal and nonverbal behavior that we are using to scaffold social interaction in children with ASD. In addition, one of the strengths of the virtual peer is that it interacts in the real world with real people rather than in a constructed virtual world enabling children to observe the effects of the social interaction.

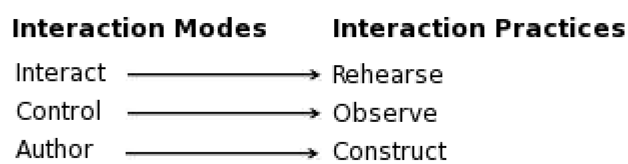

Figure 2. Virtual Peer Interaction Modes and Interaction Practices

In *interact* mode, children with autism will collaborate with the virtual peer to collaboratively tell a story, as described above with typically-developing children. For *control* mode, we are extending the interface that we currently use for our WoZ experiments (shown in Figure 3) so that children with autism can select head and body gestures, utterances, and story segments for the virtual peer to perform.

The authoring tools for the *author* mode use a flow-chart framework that helps children with ASD understand social skills and conversational goals by making the skills explicit in a way that will be familiar to them from common non-technological interventions for children with ASD. Computational objects (pictures of the behavior) are used to specify nonverbal behaviors, such as gestures and head nods, and to record plot segments of the conversational narrative, including greetings or specific social acts such as "suggest" or

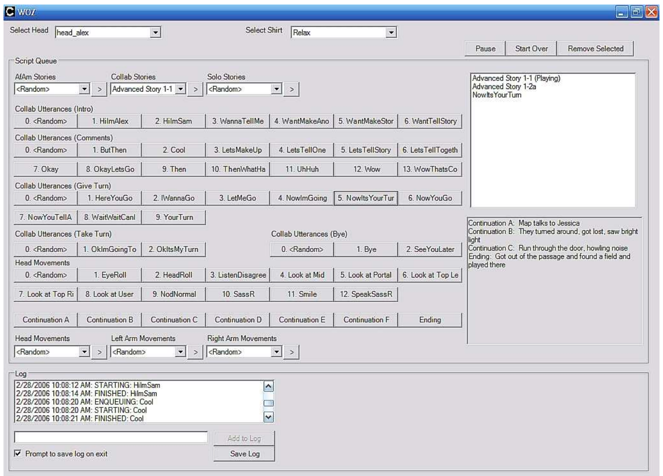

Figure 3. Wizard of Oz interface

"acknowledge." A story might, for example, be scripted to start with a "greeting" object, followed by a "suggest" object that includes a recorded portion of a personal narrative. The next object would indicate to wait for a response from the user, followed by a choice of responses for the virtual peer that can be selected in control mode. This interaction is illustrated in Figure 4.

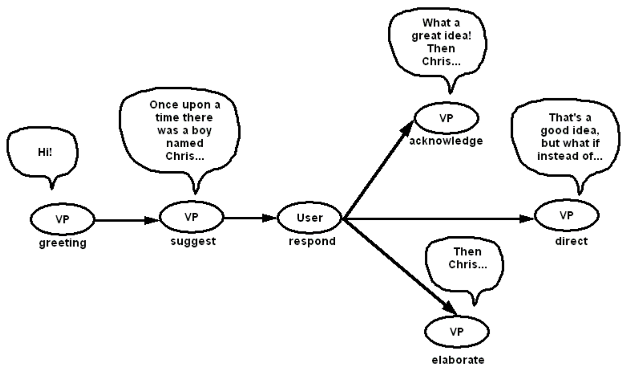

Figure 4. Example of an authored story interaction

The authoring tools are still in the design phase, however, we envision that children will first select an object representing a social act, such as a greeting. They will then work through a series of steps on different interface screens where they specify the specific speech (using audio recording or text-to-speech), eye gaze, head gestures and body gestures that the virtual peer will perform during the utterance. They can create additional objects that will be linked together (as in Figure 4) to represent the flow of the interaction between the virtual peer and the interlocutor. At run time, the virtual peer will step through this flow chart. At each virtual peer turn, the children will select which of their authored story segments should be performed. This system requires considerably more flexibility than our current virtual peer implementation allows; for this reason we are in the process of creating a new toolkit for rapid specification and implementation of full-bodied, autonomous virtual characters. This system, which is still in its early stages of development, will coordinate input and output subsystems such as text-to-speech and graphics rendering. It will be able to guide the virtual peer's behaviors, including speech utterances, phoneme timings and the co-articulation of gestures, to create coordinated graphical and speech output that successfully conveys verbal and non-verbal behavior.

The interact, control and author interactions occur cyclically, and scaffold children from simple, predictable interactions with the system to more complex, social interaction with the system. We are currently planning an evaluation of the system that will be designed such that first children spend two sessions interacting with the virtual peer to get an idea of what the system does and then controlling the virtual peer while an experimenter interacts with it. They will be invited to make Sam tell a collaborative story with the experimenter. In the next two sessions, children will use the authoring tools to build virtual peers that will interact with their friends. Children will work with an adult experimenter who will help them learn the features of the system. Over the course of five more sessions, pairs of children with autism will work together to share their storytellers (sessions 5, 7 and 9) and will also have to opportunity to revise their storytellers (sessions 6 and 8). Each child will take a turn in the "control booth" making his/her storyteller act, and observing the effect of that storyteller on the other child. At each point the experimenters will elicit the child's reaction to the interaction between the virtual peer and real child. The child can then change his or her storyteller, or create a new story, based on what they observed while their virtual storyteller was interacting with a peer. This combines the three modes of the system. Children will control their virtual peer while another child interacts with it; these interactions will likely lead to revisions of the storyteller, and children will interact with other children's storytellers.

The authorable virtual peer offers children with ASD a space to play with social communication, social interaction, and imagination - exactly the areas of impairment that characterize the deficits of ASD. Each mode of the system uses language-enabled technology to enable children to explore reciprocal social interaction in a different way. In the interact mode, a multi-modal dialog system that integrates speech and gesture provides a space for rehearsing social interactions with an indefatigable peer. In control mode, children are able to select verbal and nonverbal behaviors and observe the effects on interaction. And in author mode, children construct their own multimodal dialog system while practicing perspective-taking skills. The AVP casts children in the role of technologists by asking them to program the behaviors of a virtual character. This process of authoring virtual peers has its roots in the constructionist tradition - the use of technology as "objects to think with" [22], whereby children learn concepts such as geometry by programming robotic turtles to walk in circles, or learn about physics by building machines with levers and gears. However, while research in this tradition has concentrated on the learning of math and science, in our own work, we are extended the constructionist paradigm to learning about language and social interaction through building communicating virtual humans.

5 DESIGNING VIRTUAL PEERS

As with many language-enabled ITS (cf. [11] [41] [15] [6]), the design of virtual peers is first informed by careful study of human behavior. The focus of our current research is to develop a baseline set of interaction skills by using structured observations of children with ASD. Specifically, we ask, for children with ASD how do the verbal and nonverbal aspects of collaborative storytelling behaviors differ from those of typically-developing children? We are interested in assessing reciprocal social interactions, nonverbal behaviors associated with conversation and collaboration, and storytelling language used by children during a collaborative narrative task.

5.1 Pilot Study

Roles	Speech Act	Speaker	Function	Turn-taking behaviors
Critics and author	Suggest	Critic	To suggest an event or idea to the story	Eye gaze towards author, author may use paralanguage drawls and socio-centric sequences like "uhh"
	Correct	Critic	To correct what's been said	Eye gaze towards author
	Question	Both	To seek clarification or missing information	Eye gaze towards other, lack of backchannel feedback like head nods, increased body motion, author stops gesturing
	Answer	Both	To clarify or supply missing information	Eye gaze towards other, rising pitch, question syntax, author stops gesturing
	Acknowledge	Author	To acknowledge a suggestion or correction	Eye gaze towards critic, backchannel feedback like "mm-hmm", author stops gesturing
Facilitator and collaborator	Direct	Facilitator	To suggest storylines and designate roles	Eye gaze towards collaborator, socio-centric sequences like "OK", both stop gesturing
	Acknowledge	Collaborator	To acknowledge a role designation or storyline suggestion	Eye gaze towards facilitator, backchannel feedback like head nods, both stop gesturing
	Elaborate	Both	To narrate following suggested script	Eye gaze towards other, may start gesturing
Co-authors	Role-play	Both	Play the role of characters in the story	Eye gaze towards action, prosody of in-character voice, gesture with prop
	Simultaneous Turns	Both	Compete for turns	

Table 1. Taxonomy of Chldren's Collaborative Speech Acts

We conducted a pilot study with an eight-year-old girl with an Autism Spectrum Disorder (Asperger Syndrome), whom we will call Mary. The study investigated her verbal and non-verbal behaviors in an interaction with our virtual peer Sam, and compared them to our existing model of collaboration in typically-developing children. After the experimenter introduced Mary to Sam, Mary and Sam told two collaborative stories together where Mary and Sam took turns adding to the story, Mary initiated one story with Sam, and then Mary requested that Sam continue telling stories for two stories.

After transcribing the session, we coded Mary's stories for various verbal and non-verbal forms, based on our model of collaborative storytelling in typically-developing children, summarized in Table 1. This model was created by Wang and Cassell [50] by analyzing pairs of children telling stories using a toy house and figurines as props. This taxonomy is not a complete characterization of children's speech acts during storytelling, but includes all of the acts that result in turns being exchanged [50]. Each of Mary's speech acts was given one label chosen from: Author-Acknowledge, Author-Answer, Author-Question, Critic-Answer, Critic-Question, Critic-Correct, Facilitator-Elaborate, Facilitator-Direct. Collaborator-Elaborate, Collaborator-Acknowledge, Coauthor-SimultaneousTurn, Coauthor-RolePlay, Nonstory-comment, or Response-Sam. We then coded her non-verbal behavior including: (1) eye gaze: Towards Sam, Towards Physical Toys, Towards Virtual Toys, Towards another Human, or Away; (2) head nods; and (3) gesture with the toys, which was coded for both Form (Hold Toy, Move Toy, Examine Toy) and Function (Narrative corresponding to Sam's or the child's story, and Non-narrative). We then looked at co-occurrences of speech acts with the different non-verbal behaviors.

First it should be pointed out that Mary engaged with Sam with notable enthusiasm, exclaiming after Sam spoke for the first time, "It interacts to us!" This is in stark contrast to interactions with her peers which are marked by avoidance of social groups. Her speech acts included collaborator-elaborate (7), response-sam (7) and non-story comment (3), demonstrating her ability and interest in listening and responding to Sam. The following examples illustrate each of the speech acts:

Example 1: Collaborator-elaborate

Sam: (starts a story about Jack and Mary, two kids playing hide and seek. Sam ends its segment by saying) Mary shouted, "No peeking" and ran off. She, mmm, then she...

Mary: Hid in the bathtub.

Example 2: Response-Sam

Sam: Now it's your turn

Mary: No thanks

Example 3: Non-story comment

Mary: He interacts to us

In addition, when Sam asked her to tell a story, she facilitated her own story about a girl who made the "water messy" while taking a bath and had to start her bath all over again after her brother yelled at her (including one segment coded as facilitator-elaborate). However, notably missing from her interactions are speech acts including role-playing as a co-author, and suggesting, directing, questioning or acknowledging as a facilitator, collaborator, author or critic.

Mary's eye gaze and play gestures further illustrate her engagement with Sam. Our model of collaborative storytelling describes elaboration speech acts as characterized by "eye gaze towards the other" and "may start gesturing." When Mary used these speech acts, her gaze moved back and forth between Sam and the physical toys, and she incorporated gestures with the toys into her stories, as illustrated in Table 2. Likewise, during Sam stories, Mary's gaze moved back and forth between Sam and the physical toys, which she was using to act out the story that Sam was telling.

	Non-story Comment	Response-Sam	Collaborator-Elaborate	Facilitator-Elaborate
Eye Gaze				
To physical toys	1	1	6	5
Away	1			
To Sam	2	7	10	5
Gesture				
Non-narrative				
Hold	1	4		1
Move		2		
Examine	2		1	
Narrative				
Child story narration			4	1
Sam story narration			1	
Head Nod		1		

Table 2. Summary of Eye Gaze, Gestures and Head Nods Co-occurring with Mary's Speech Acts

5.2 Applying the Results

This coding scheme can be used in two ways: (1) to characterize the collaborative storytelling behavior of children with autism as compared to our model of collaboration in typically-developing children; and (2) to examine the specific behaviors of an individual child to personalize the kinds of behaviors she can improve using an authorable virtual peer.

As we collect more data from children with ASD interacting with other children and with Sam we will be able to work toward this first goal of characterizing the collaboration deficits of children with ASD in a specific task – storytelling with a peer. We hypothesize that children with autism will exhibit deficits in the use of storytelling roles, speech acts and turn-taking behaviors. This hypothesis is based on previous research on narrative ability in autism that shows children with ASD produced impoverished narratives when compared to typically-developing children matched for mental age, and may not provide causal explanations for the events in their stories [45]. Children with ASD are less able than typically-developing children to consider the listener's needs when constructing stories, and produce more bizarre or inappropriate utterances [31]. These findings reflect lack of awareness of audience and inability to collaborate with peers to make meaning, which are considered by many researchers to be the key to some of the social deficits associated with autism [46]. Our observations may contribute to a deeper understanding of these deficits by investigating in more detail the specific speech acts performed and not performed; they will also inform the design of our system.

Experiments of this sort will allow us to supplement our model of collaborative storytelling in typically-developing children (Table 1) with a second model, of the collaborative storytelling deficits in autism. Currently, our model of collaborative storytelling with typically-developing children is implemented in our virtual peer Sam. Many language-enabled ITS model the tutor or the user, or both [11] [41] [15] [6]. Similarly, we have used our models of typically-developing children to design the specific speech acts and turn-taking behaviors (gestures, head movements, eye gaze, etc) implemented in the virtual peer. In this project we must take this implementation of the model one step further – the system must implement the models such that the virtual peer executes coordinated speech and non-verbal behaviors as typically-developing children do, but it must also model the lacunae of the user in such a way as to enable children with autism to author, control and observe the different reciprocal interactions in exactly those areas where they have deficits.

Toward the second goal, we observed in Mary several areas where an authorable virtual peer could be used to practice different interactions. As described above, Mary's interactions lacked certain speech acts including role-playing as a co-author, and suggesting, directing, questioning or acknowledging as a facilitator, collaborator, author or critic. Role-playing enables children to practice imaginative play, while suggesting, directing, questioning and acknowledging are all reciprocal social interaction speech acts. The authoring tools will use computational objects to represent these different speech acts (ie. a "suggest" object, an "acknowledge" object, etc.), and thus provide opportunities for children to explicitly author both the verbal and nonverbal aspects of these interactions. Using the technology to elicit different collaborative speech acts will strengthen the potential of a virtual peer intervention and, we hope, ultimately the children's interactions with each other.

6 CONCLUSION

In the current work we leverage the advances in language-enabled technologies to support the development of communication and reciprocal social interaction skills. We use language technologies in three interaction modes that engage children in three interaction practices. First, by engaging in natural language dialog in a storytelling task, children rehearse verbal and nonverbal interaction skills with an indefatigable peer. Second, by controlling the virtual peer, children manipulate the verbal and nonverbal behaviors of the peer and observe the effects on interaction. Finally, children construct interaction examples by authoring their own dialog system for the virtual peer. To inform the design of this system, we first carry out an investigation into both the verbal and nonverbal aspects of peer collaborative storytelling skills, when children with ASD are in the context of human peers and virtual peers. In this paper, we describe a one child pilot study toward this goal, including our coding scheme for analyzing the child's behaviors and a summary of this child's interactions with the agent according to this scheme. We describe how these results are used to design the virtual peer and personalize the intervention for the individual child. We hypothesize that the results from these studies will add to our understanding of autism itself, and lead to the design of improved interventions to help children take advantage of the scaffolding of the social world around them.

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Autism is a spectrum disorder, meaning that there is a wide degree of variation in the way it affects people. Every child on the autism spectrum has unique abilities, symptoms, and challenges. Learning about the different autism spectrum disorders will help you better understand your own child, get a handle on what all the different autism terms mean, and make it easier to communicate with the doctors, teachers, and therapists helping your child. Understanding autism spectrum disorders. Autism is not a single disorder, but a spectrum of closely related disorders with a shared core of symptoms. Autism spectrum disorder (ASD) is a condition that affects social interaction, communication, interests and behaviour. In children with ASD, the symptoms are present before three years of age, although a diagnosis can sometimes be made after the age of three. It's estimated that about 1 in every 100 people in the UK has ASD.