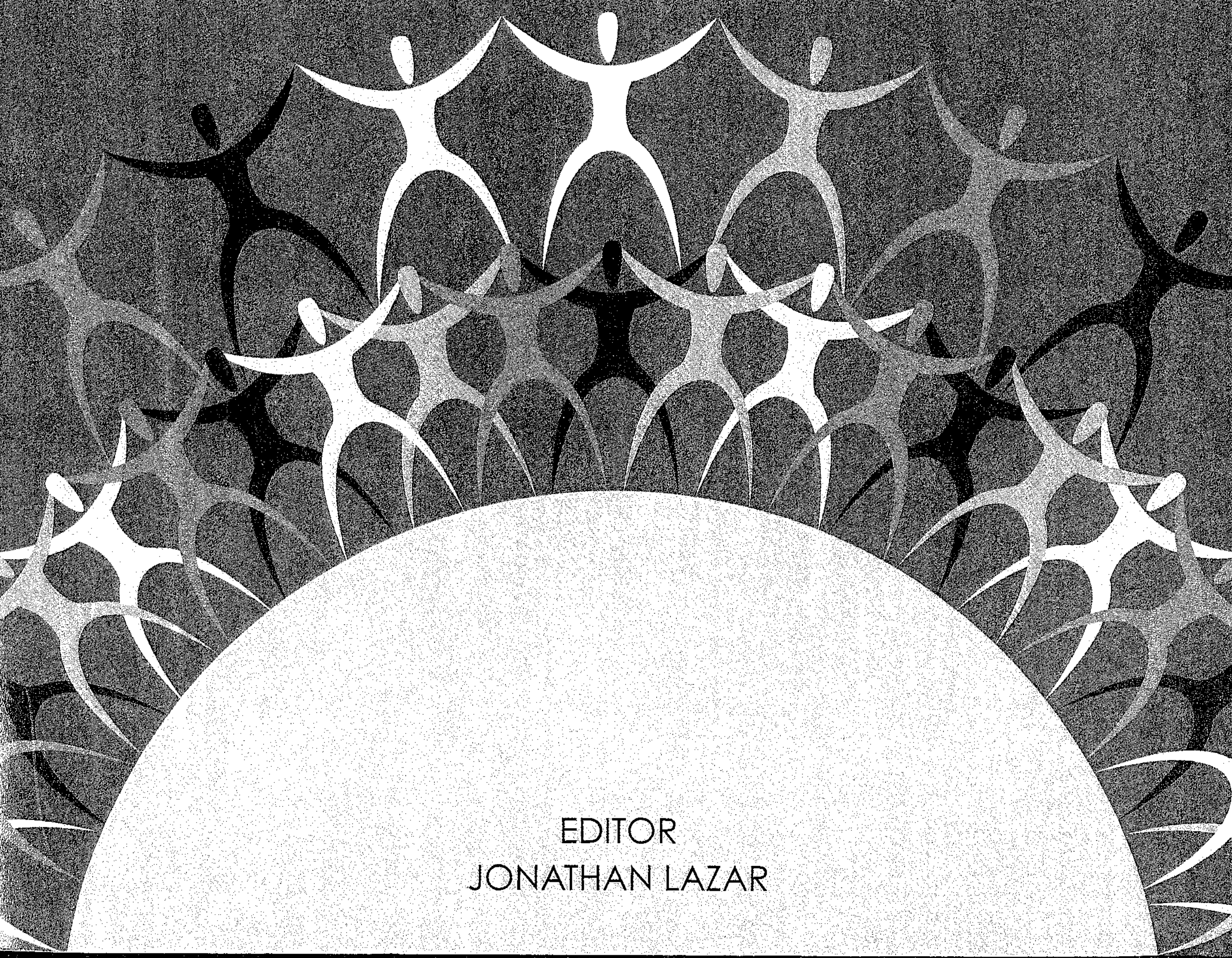
UNIVERSAL USABILITY

Designing Computer Interfaces for Diverse Users



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Designing Computer Interfaces for Diverse User Populations

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8 Using Virtual Peer Technology as an Intervention for Children with Autism

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Summary

In this chapter we discuss the motivation, design, and implementation of PAT (Play and Tell), an *authorable virtual peer* for children with autism spectrum disorder (ASD). Based on research on the triad of impairments that characterize ASD, and how these impairments may be linked to deficits in theory of mind, we lay out a set of key features that we believe to be important – and as yet undervalued – in technological interventions for children with autism: (1) a peer context, rather than a virtual parent or teacher, so that children can practice peer social interaction skills; (2) a personally meaningful storytelling task for practicing imagination and language; (3) a system that incorporates not just interaction with the technology, but also a control and author mode, to allow the child to build appropriate social skills from the ground up. These features are instantiated in an authorable, life-size, full-body virtual peer that tells collaborative stories and thereby gives children with ASD a space to play with social interaction, communication, and imaginative play behaviors. Pilot studies demonstrate that for at least some children with ASD and related diagnoses, the PAT system is intuitive, motivating, and capable of engaging children in the kind of tight reciprocal social interaction that is otherwise so difficult for them, and that is the basis for both play and learning among children.

Introduction

Instructional technologies increasingly integrate a social as well as a cognitive component to help scaffold learning. Thus, virtual peers (Ryokai *et al.*, 2003), affective pedagogical agents (Johnson and Carlisle, 1996; Lester *et al.*, 1997; Gratch, 2000), interactive pedagogical dramas (Si *et al.*, 2005), and peer-directed online learning communities (Cassell, 2002) are all leveraging the ability of the computer to create a social context for learning. However, the Universal Usability tradition in human–computer interaction research reminds us not to take for granted that new technologies are usable by all populations (Shneiderman, 2000), and on examination these social learning technologies may be least usable by a population that needs them most. 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. And yet we know from the reports of parents, teachers, therapists, and researchers (cf. Hart, 2005), that many children with ASD show an affinity for computers. Instead of labeling these technologies as useless for children with ASD, in this chapter we propose to leverage the social context that is created in these systems to help develop social and communication skills. In particular, this chapter proposes a computer system called 'Play and Tell' (PAT) that allows children with ASD to tell stories with a life-size, indefatigable virtual peer, as well as to control and to author interactions for that virtual peer. PAT incorporates three features which we believe will be crucial to its success as an intervention for children with ASD: (1) a virtual peer context so that children can practice peer social interaction skills; (2) a personally meaningful storytelling task for practicing imagination and language; (3) a system that is controllable and authorable by the child to allow children with ASD to come to understand and scaffold their own communication and reciprocal social interaction in typical social settings. An additional goal of the system is to allow researchers to better understand the mechanisms underlying the communicative deficits of ASD by observing children with ASD interacting with the storytelling virtual peer, and authoring interactions for it.

In what follows we first describe autism spectrum disorder, provide a theoretical framework of ASD deficits in terms of theory of mind, give some estimates on the prevalence of ASD, and explain why social skills development is crucial for children with ASD. Next we summarize previous nontechnical and technical interventions for children with ASD, and examine the key features of the interventions that contribute to their success. We then introduce the three key features of our own intervention: virtual peers as partners in learning, storytelling as a developmental task, and a system for controlling and authoring social interactions. We describe PAT, our authorable virtual peer for children with ASD, and describe our methodology for designing and evaluating virtual peers. Finally, we offer some initial findings from our pilot studies, and conclude with the implications of our work for designers, researchers, and policymakers.

8.1 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) (NAS, 2005).

These deficits manifest themselves in a variety of ways. For example, individuals with ASD may be echolalic (they repeat or echo what they overhear) and may speak in monotone. Individuals with ASD have difficulty understanding what others are feeling and may need to be explicitly taught social skills that typically developing children pick up incidentally. Their play may lack imagination (Brill, 2001). 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 (Brill, 2001).

Asperger syndrome, pervasive developmental disorder – not otherwise specified PDD-NOS, and nonverbal learning disorder (NLD) are all diagnoses related to autism. Of these, Asperger syndrome and PDD-NOS are characterized as disorders on the autism spectrum. Thus, people with Asperger syndrome have similar social difficulties, but have normal or above-average intelligence (Ghaziuddin and Mountain-Kimchi, 2004). Similarly, a diagnosis of PDD-NOS is given when children demonstrate autistic social and communicative disabilities, but do not fully meet the diagnostic criteria for other pervasive developmental disorders diagnoses (Paul *et al.*, 2004). For the most part, individuals with Asperger syndrome and PDD-NOS show higher verbal abilities than those with autism (Ghaziuddin and Mountain-Kimchi, 2004; Paul *et al.*, 2004).

Nonverbal learning disorder is a neurological syndrome (not on the autism spectrum) that many consider to be a mild form of autism (Little, 1999). Individuals with NLD have high verbal ability, and in fact may speak well and be verbose, but they have significant problems with social skills, academics, visual–spatial abilities, and motor coordination (Little, 2003). Similarly to children with autism, they often have difficulty deciphering the communicative intent of nonverbal behaviors such as tone of voice, gesture, facial expressions, nuances, and body language (Little, 2003). They may interrupt conversations and change the subject to unrelated and irrelevant issues. Integrating new information and applying learning from one situation to another is also problematic for children with NLD; it is therefore difficult for them to cope with new situations (Little, 1999).

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 (Baron-Cohen, 1995). 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. This kind of lack of understanding can be illustrated by the following excerpt from *The Curious Incident of the Dog in the Night-time* (Haddon, 2003), a novel told from the point of view of a child with ASD:

> And one day Julie sat down at a desk next to me and put a tube of Smarties on the desk, and she said, 'Christopher, what do you think is in here?'
>
> And I said, 'Smarties.'
>
> Then she took the top off the Smarties tube and turned it upside down and a little red pencil came out and she laughed and I said, 'It's not Smarties, it's a pencil.'
>
> Then she said, 'If your mummy came in now and we asked her what was inside the Smarties tube, what do you think she would say?'. . .
>
> And I said, 'A pencil.'
>
> That was because when I was little I didn't understand about other people having minds. And Julie said to Mother and Father that I would always find this very difficult. (Haddon, 2003, pp. 115–116)

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 (Tager-Flusberg, 2000). For example, one of the components of theory of mind is the shared attention mechanism (Baron-Cohen, 1995), or joint attention, which is the ability to form a triadic representation between the self, another, and an object by monitoring the eye direction of the other agent to interpret mental states. In lay terms this means that in conversation most people monitor each other's eye gaze, and look in the direction that their conversational partners are looking in order to see what the conversational partner is attending to. While children with ASD can understand that motion serves a goal or a desire (for example, reaching for something may mean one wants it), and can detect people's eyes and infer that those people see what they are looking at, they appear to have an impairment concerning joint attention and do not understand that the activities of the other may be intended to make meaning for the child. Thus, children with ASD do not demonstrate gaze monitoring, nor do they attempt to direct the attention of another person (Baron-Cohen, 1995). The absence of joint attention causes a problem because it forms a critical scaffold to learning. For example, vocabulary is learned during episodes of joint attention (such as when a mother says 'that's a dog' and directs her eyes to the animal), and joint attention also plays a key role in pretend play (Jones and Carr, 2004).

8.1.1 Prevalence of Autism Spectrum Disorder

The National Autistic Society (UK) estimates the total rate of prevalence of autism spectrum disorders in the UK to be approximately 1 in 110 (NAS, 2005). The Autism Society of America estimates a rate of autism of 1 in 166, or 1.5 million Americans

(ASA, 2005). Because clinicians and researchers are seeing increasing numbers of children for assessment, diagnosis, and treatment of autism spectrum disorders, there is a strong sense that ASD has become more prevalent in recent years (Prior, 2003). In fact, up until 1990, ASD was considered a rare disorder with an occurrence of 4 per 10000 children. However, it is debatable how much these increases represent an actual rise in the disorder (Prior, 2003). Possible alternative explanations include changes in diagnostic practices, heightened awareness and acceptance among parents and educators, and improved services for children with ASD, such that parents may be willing to bring their children in for diagnosis (Charman, 2002; Prior, 2003).

8.1.2 Social Skills Deficits

Although children with ASD may manifest a number of differences from their typically developing peers, the current chapter focuses on social skills. More exactly, we focus on social communication and reciprocal social interaction – that is, 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 particular deficits in children with ASD can impact children's personal relationships, education and employment opportunities (Webb *et al.*, 2004), and have been particularly resistant to intervention, making them an area that needs further research. In addition, the perceived value of social skills instruction is high. In a survey of maternal perceptions of the importance of needs and resources for children with Asperger syndrome and nonverbal learning disorders, 78% of mothers rated social skills training as extremely important. The study also concluded that schools are not providing sufficient social skills training (Little, 2003).

When reciprocal social interaction is successful, communication is seamless, and the participants may even experience an increased feeling of rapport with the conversational partner, which itself serves as a foundation for learning. Successful communication of this sort, however, is composed of exactly the kinds of behavior that are difficult for individuals with ASD: joint attention, positivity toward the other as demonstrated in words and nonverbal behavior, and coordination of speech behavior and social interaction (Tickle-Degnen and Rosenthal, 1990). We have examined some of this work in our implementation of an 'embodied conversational agent' that engages in small talk and social dialog (Cassell, 2002; Bickmore and Cassell, 2005). We translated the concepts verbally into shared patterns of speech, and increasing coordination in speaking, and nonverbally into behaviors such as body postures that signal accessibility, smiling, head nodding, postural mirroring, and interactional synchrony. Our results showed that users demonstrate increased trust of an interaction with a virtual human when that virtual human engages in these relational behaviors. In the current work, we hypothesize that one of the ways that we can address impairments in theory of mind in ASD is by modeling these surface-level rapport behaviors in embodied virtual peers, allowing the children to tweak the behaviors themselves and observe the outcome on communication.

8.2 Interventions for Children with Autism Spectrum Disorder

Nontechnological approaches that target the social interaction deficits of ASD have existed for quite some time with fairly good results (Faherty, 2000). For reciprocal social interaction, such as gaining a listener's attention, initiating topics, maintaining topics, and expressing ideas, 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.

8.2.1 Social Groups

Social groups target improvement in social skills such as perspective-taking, reciprocal interactions, listening skills, turn-taking during games and conversations, etc. (Faherty, 2000). Social groups vary in how much structure they provide on social interactions, 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. Activities used to structure the social group may include games, sports, crafts, or music. Some general guidelines often followed by social groups include: meeting on a consistent basis, keeping the group small, beginning each meeting with a common routine, displaying a schedule of events, providing structure and visual cues, using social stories (below) to clarify problematic situations, including a snack or meal, discussing and voting on what the group will do next, and concluding with a familiar routine (Faherty, 2000).

LeGoff (2004) studied a social group that used Lego as a medium to develop social skills in children with autism. A key feature of Lego as a therapeutic tool is that the medium has a 'constructive application' – it relies on children's natural interests to motivate learning and behavior change. The goal of Lego therapy is to increase social competence along three dimensions: (1) motivation to initiate social contact with peers; (2) ability to sustain interaction with peers for a period of time; and (3) overcoming autistic symptoms of aloofness and rigidity. A key strategy involves dividing the task of building into two roles: the 'engineer' and the 'builder.' Much of the communication requires nonverbal behavior, with an emphasis on joint attention, eye contact, and 'mind-reading.' The unique aspects of the Lego therapy are: (1) blending of individual and group therapies; (2) use of play materials (Lego) which were inherently interesting and motivating to the clients, and providing a medium for promoting social interaction, collaboration, and interactive play; and (3) creation of a social group.

8.2.2 Peer Partnerships

Identifying 'buddies' or 'peer helpers' is another technique used to facilitate friendship and interaction skills in children with autism. Peer partners 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 structured strategies used by the child with autism (Faherty, 2000).

8.2.3 Social Skills Training Programs

Social skills training programs such as the SCORE Skills (Vernon *et al.*, 1996), Skillstreaming (McGinnis and Goldstein, 1984, 1990) and Social Effectiveness Training (Jackson *et al.*, 1991) 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. As skills are practiced, it should become more natural to carry out the skill steps. A recent study demonstrates the effectiveness of using the SCORE Skill Program with adolescents with high-functioning autism (Webb *et al.*, 2004).

Similarly, Skillstreaming (McGinnis and Goldstein, 1984, 1990) uses structured learning techniques of modeling, role playing, performance feedback, and transfer of training to teach children specific pro-social behaviors. The program groups skills into: beginning social skills, such as 'listening' and 'asking for help'; school-related skills, such as 'asking a question' or 'following directions'; friendship-making skills, such as 'joining in' and 'sharing'; dealing with feelings, such as 'asking to talk' or 'showing affection'; alternatives to aggression, such as 'dealing with teasing' and 'being mad'; and dealing with stress, such as 'being honest' and 'saying no.' Social Effectiveness Training (Jackson *et al.*, 1991) 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. Groups of six to eight clients meet with two instructors for one to two hours weekly or biweekly. Each session reviews one or two specific social skills, such as 'interrupt the right way' or 'join in.'

8.2.4 Narrative and Pictorial Interventions

A common intervention employing narratives that model social competencies is the 'social story,' developed by Carol Gray in 1991. A social story defines relevant cues in a social situation and describes appropriate responses (Gray, 1994b). For example, a social story can involve a specific activity, such as homework time. The child's behavior during this activity is analyzed to determine what situations cause undesirable behaviors, such as crying and hitting. These situations are described in the story and inappropriate behaviors are contrasted with correct actions. For example, if a homework problem is hard, the child should not scream, but rather ask someone for help. The components of the strategy include: social modeling, task analysis, visual aides, practice with corrective feedback, and priming. Figure 8.1 gives an example of a social story written to support a student in following her daily schedule.

A small amount of recent research has provided empirical evidence on the effectiveness of social story interventions (Adams *et al.*, 2004; Barry and Burlew, 2004). Both these studies described case studies where social story intervention was effective for the situation target, and even transferred to other situations.

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 (Gray, 1994a). Comic Strip Conversations use a set of eight symbols to represent basic conversational skills, including 'listening,' 'interrupting,' 'loud' and 'quiet words,' 'talk,' and 'thoughts.' Thus the drawings can represent not only what people are saying and doing but also emphasize what people may be thinking. Comic Strip Conversations are said to leverage visualization and visual supports, techniques found useful in structuring learning in students with autism.

A similar technique, Social Skills Picture Stories, uses digital pictures of actual children demonstrating various social skills (Baker, 2001). The pictures are combined with text and cartoon bubbles to denote what the children are saying and thinking. Social Skills Picture Stories break down 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.

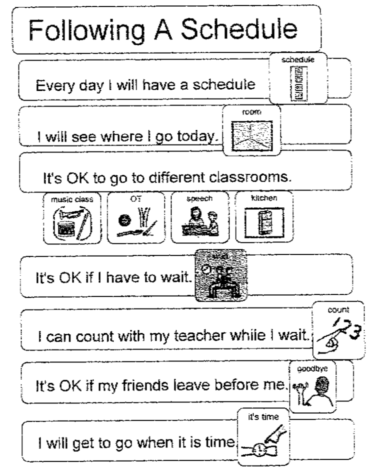

Figure 8.1 Example social story written to support a student in following her daily schedule. Written by Nicole Ruschmeyer, M.A., CCC-SLP/L, Speech-language Pathologist, Clinical Assist, Ltd. The Picture Communication Symbols ©1981–2006 by Mayer-Johnson LLC. All Rights Reserved Worldwide. Used with permission. Boardmaker is a trademark of Mayer-Johnson LLC.

8.3 Technology and Autism Spectrum Disorder

There has been a recent increase in computational systems for children with ASD. Often these projects rely on proven techniques to address the social and learning needs of children with ASD: story telling (Davis *et al.*, 2004), animated cartoon characters (Bosseler and Massaro, 2003; Cole *et al.*, 2003; Wise *et al.*, in press), socially situated learning (Dautenhahn *et al.*, 2002; Kerr *et al.*, 2002; Dautenhahn and Weery, 2004; Parsons *et al.*, 2004; Robins *et al.*, 2004), and tracking and evaluations of treatments (Hayes *et al.*, 2004).

Davis *et al.* (2004) created a system called Touch Story to explore the ability of children with ASD to build coherent stories. The system tested whether children with ASD could select the third frame in a five-frame picture story. While their research demonstrates the use of storytelling in interventions for children with ASD, it does not go further in exploring storytelling as a context for exploration of language, imagination, or social interaction.

The Aurora project (Dautenhahn and Weery, 2004) built a series of 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. They have found that children with ASD will proactively approach robots (Dautenhahn *et al.*, 2002), and that robots can be used to elicit joint attention episodes between children with ASD and an adult (Robins *et al.*, 2004). In addition, by slowly increasing the repertoire and unpredictability of the robot's behavior, the robot can be used to guide a child to more complex forms of interaction (Dautenhahn and Weery, 2004). Similarly, Michaud and Theberge-Turmel (2002) describe several robots that offer different behaviors and rewards to appeal to different children. Their goal is to design robots that can evolve with the child from simple machines to robots that demonstrate more complex behaviors.

These different robot therapies demonstrate two key features of systems for children with ASD: (1) because of the diverse profiles that characterize children with autism, the system must be highly personalizable to adapt to the needs, interests, and abilities of each child that interacts with it; and (2) even more than for typically developing children, it is helpful if the system can provide a scaffold for learning that is withdrawn little by little as the child's competencies grow.

Virtual environments have proven to be another active area of research for social skill interventions. Kerr *et al.* (2002) have designed a number of single-user and collaborative virtual environments that teach social skills for adolescents and adults with Asperger syndrome. They emphasize the importance of scaffolding in the system that can guide users through the learning process. In addition, they use two scenarios, a virtual café and a virtual bus, which share a common goal (to find a seat) to explore transfer of learning from one context to another.

Similar research evaluates a desktop virtual environment for people with ASD, where users were represented by avatars (Parsons *et al.*, 2004). This environment proved to be intuitive to individuals with ASD, who were able to learn to use it quickly. In fact, the users with ASD were able to interpret the environment in a nonliteral way, for example by concluding that two figures standing by a bar in a virtual café were talking. Interestingly, participants with ASD were more frequently rated as walking between or bumping into the people at the bar and more likely to be judged as having 'low intention to avoid' a couple at the bar, compared with matched counterparts. The authors conclude that this reflects a weak understanding of appropriate behavior concerning personal space in people with ASD that even translates into the virtual environment.

Bosseler and Massaro (2003) evaluated the effectiveness of an animated cartoon agent vocabulary tutor for children with ASD. The studies found that children 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. 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 (Animated Speech Corporation, 2002, 2005). The Center for Spoken Language Research at the University of Colorado (Wise *et al.*, in press) has also tested a literacy education system for children with ASD. The system uses a cartoon face to give hints and explanations to children as they complete phonological awareness, reading, spelling, and comprehension exercises. In both of these cases, an animated tutor motivates children, and gives them immediate feedback on their performance. However, neither project provides the *peer* context that is so important to learning about social skills and about literacy, nor a full-bodied animated agent that can allow children with ASD to learn about the role of the body in social interaction. And, in both projects, content is authored by the teachers, and there is not room for children to explore imaginative play or the behaviors of reciprocal social interaction by authoring their own stories – and their own animated agents.

CareLog uses automated capture techniques to track the effectiveness of educational and therapeutic interventions for children with ASD (Hayes *et al.*, 2004). This software enables members of care teams for an individual child to automatically capture, measure, mine, and analyze behavior and learning data. The system helps coordinate caregivers, and uses data to affect treatment and future data capture.

8.4 Guidelines for Using Technology in Social Interventions

The researchers who have implemented and evaluated these previous technological and nontechnological social skill and language interventions emphasize a certain number of features that appear to be key to success in designing for the population of children with ASD. These features include:

- *Interventions are highly personalizable.* Social stories, for example, are tailored to a specific child's behavior in a particular situation (Gray, 1994b; Adams *et al.*, 2004; Barry and Burlew, 2004). The robots described by Michaud and Theberge-Turmel (2002) exhibited different behaviors and reward sequences to appeal to the preferences of children.

- *Systems scaffold the child.* In the Aurora project (Dautenhahn and Weery, 2004), the behaviors first exhibited by the robots are simple and predictable. As children interact more with the robots they become more complex. This progress from simple, predictable behaviors to more complex interactions is common in therapies designed for children with ASD, and adapts children to social interaction.
- *Artifacts have constructive applications.* The success of the Lego therapy was greatly influenced by the natural appeal of the Lego artifact (LeGoff, 2004).
- *Using roles helps children with ASD practice social interactions.* By taking on roles of 'engineer' and 'builder' during the Lego therapy, children were encouraged to interact to complete a task (LeGoff, 2004). Also, the roles provide a script the children can learn and follow to scaffold their interaction.
- *Social contexts provide an environment for practicing social skills.* Virtual environments use the context of a café or bus to practice behavior in a social situation (Kerr *et al.*, 2002; Parsons *et al.*, 2004). Social groups create a safe space for practicing peer interaction.
- *Evaluation considers the transfer of behaviors to other contexts.* That children with ASD have trouble transferring learned behaviors to different contexts must be remembered when designing systems and revisited in their evaluation.

Our goal is to design a technology intervention that incorporates these features but adds three additional features that we know to be important from research on typically developing children: (1) a peer context, rather than a virtual parent or teacher, so that children can practice peer social interaction skills; (2) a personally meaningful storytelling task for practicing imagination and language; (3) a system that is authorable by the child, to allow the child to literally build appropriate social skills from the ground up.

8.5 Virtual Peer Support for Learning

A virtual peer is a life-sized, full-body computer-generated animated character that looks like a child and is capable of interacting with children by sharing real toys and responding to children's input. Sam, the virtual peer shown in Figure 8.2, was developed as a way to promote language and literacy development in children by leveraging oral storytelling and communication skills, engaging children in peer play, and supporting imaginative play (Ryokai *et al.*, 2003; Cassell, 2004). Sam's speech and body behaviors are modeled after the storytelling roles and turn-taking behaviors that children use when interacting with each other.

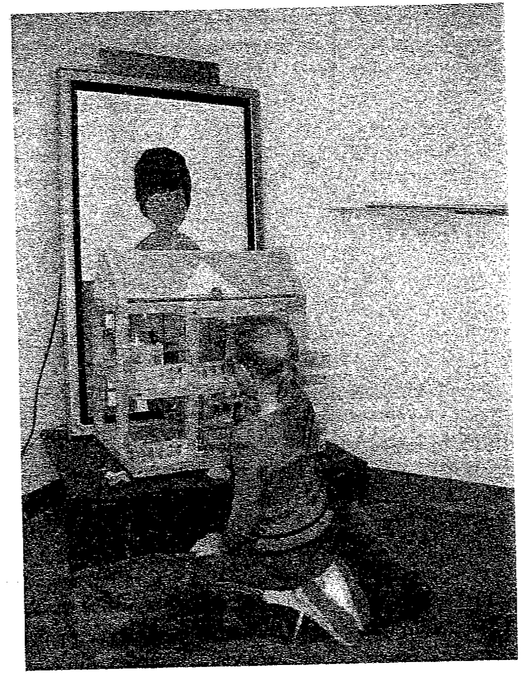

Figure 8.2 Sam.

Sam tells stories with children using a castle placed in front of the child that 'extends' into Sam's virtual world, and toys that pass between the virtual and physical world through a 'magic portal' in the castle. Sam has been implemented in Macromedia Flash. 3D animations are created using a character animation tool, and then imported into Flash, where they are edited so that the body parts can be controlled independently. Sam's voice is a set of pre-recorded audio clips, which offer more realism than text-to-speech. Some of Sam's behaviors are generated automatically, such as Sam's eyebrows, which rise for emphasis with changes in pitch in the speech, and Sam's lips, which move as a function of the sounds of the words that Sam utters. Other behaviors are scripted by hand.

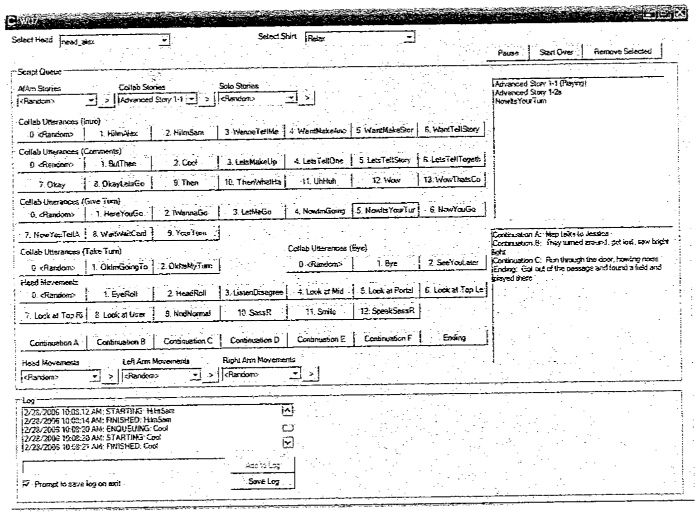

Figure 8.3 Wizard of Oz control interface.

Since speech recognition of children's voices is very difficult, the Sam system relies on an audio threshold to determine when the child is speaking. RFID tags on the toys and sensors in several rooms of the house are used to direct Sam's head animations so s/he is always looking where the child is playing, and as a clue to turn-taking when children put the toys back into the 'magic portal,' completing a storytelling turn.

To evaluate Sam's interactions with children, we rely on a Wizard of Oz (WOZ) control interface (Figure 8.3) that enables the experimenter to select Sam's pre-recorded responses and story segments. The experimenter is trained to select responses based on the same algorithm used by the autonomous system.

8.6 Storytelling

Because literacy is fundamentally about producing language in a way that others can understand, and understanding language that others have produced, the audience or listener plays an essential role in literacy learning. For this reason, typically

developing children first acquire literacy skills in social contexts such as language play and storytelling, and many of these skills are acquired in the context of children's interactions with peers (Snow, 1983). Peer storytelling is a particularly relevant context for literacy development because it encourages children to produce 'decontextualized language.' Decontextualized language is language for an audience that does not share the same temporal and spatial context (Snow, 1983). For example, 'tomorrow' and 'here' are contextualized language because the listener must share the same time and place as the speaker to understand the meaning. 'One Spring day' or 'in the library at Northwestern University' are examples of decontextualized language because they convey a place or time that can be understood without knowing who the speaker is, or when s/he has spoken. Storytelling requires children to hold the audience's perspective in mind while relating the context of a story (Cameron and Wang, 1999). In addition, children are demanding listeners, co-authors, and critics of one another (Preece, 1992; Sawyer, 2002), meaning that peer storytelling is also a social interaction exercise.

Lack of awareness of audience and inability to collaborate with peers to make meaning are considered to be key signs of ASD. In fact, children with ASD produce impoverished narratives when compared with typically developing children matched for mental age, and may not provide causal explanations for the events in the stories (Tager-Flusberg, 1995). Loveland *et al.* (1990) found children with ASD are less able to consider the listener's needs when constructing stories, and produce more bizarre or inappropriate utterances.

These deficits in narrative ability have been interpreted as reflective of autism's underlying deficits in theory of mind (Tager-Flusberg, 2000). Capps *et al.* (2000) investigated the relationship between social competence and narrative in more detail. They found that theory of mind abilities are related to two fundamental aspects of narrative: (1) narrative as a social activity that involves monitoring and maintaining listener involvement; and (2) narrative as a means of elaborating a point of view concerning characters' emotions, thoughts, and actions. Thus, creating a collaborative storytelling task that enables children with ASD to develop their narrative skills addresses the underlying theory of mind deficits of ASD. At the same time, it creates a peer context for observing and practicing social skills. Although psychologists often use open storytelling as a diagnostic tool for children with ASD, and reading or retelling stories appears in many interventions for children with ASD, few interventions ask the children to collaborate to tell unconstrained and personally meaningful stories, and none to our knowledge allow children to engage in the key developmental task of collaborative storytelling with peers. And yet, the research described above leads us to believe that storytelling with a virtual peer can allow children to practice turn-taking behaviors, take on conversational roles, address the beliefs of peers, and stretch their imaginations.

8.6.1 PAT: a Virtual Peer Authoring System for Children with ASD

On the basis of the research reviewed above, and the key features extracted from interventions designed by others and our own previous work on typically developing children, we are designing, creating, and evaluating the use of a new kind of 'authorable,' life-size, full-body virtual peer for children with ASD: PAT (Play and Tell). PAT is used in three modes. Children with ASD interact with the virtual peer by telling stories. In a second mode, children also control the virtual peer by using the Wizard of Oz interface to select predefined responses, thus practicing and observing different behaviors through the agent. Finally, in the third mode, children author the virtual peer by creating new behaviors and responses. These interactions occur cyclically, as illustrated in Figure 8.4, and scaffold children from simple, predictable interactions with the system to more complex, social interaction with the system. 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. We believe that collaborative storytelling with a virtual peer will help children with ASD develop narrative and social interaction skills.

Each mode of the system is controlled by a different interface. In *interact* mode, children tell stories with the virtual peer while the virtual peer is controlled by an experimenter, or a peer, using a WoZ interface. For the *control* mode, in conjunction with the children themselves, we are developing a child-friendly version of the experimenter's WoZ interface so that the children can control the behaviors of the virtual peers. Children can turn on and off the nonverbal behaviors of the agent, such as eye gaze, hand gestures, head nods, and observe the effects on interaction. A pilot study demonstrated that even the adult-oriented Wizard of Oz control panel that we

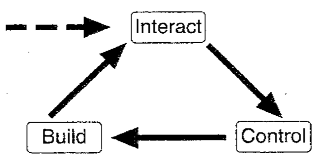

Figure 8.4 Authorable virtual peer interactions.

currently use is intuitive for some children with ASD, who were very interested in using the interface to control the behaviors of a virtual peer.

Finally, for the *author* mode we are creating child-friendly story- and behavior-authoring tools for virtual humans. Currently, stories are scripted by hand by timing gestures to audio files by the millisecond. With new authoring tools, children will be able to record or type story segments, and select sequences of gestures to accompany the utterances. Building their own virtual storytellers enables the children to practice decentering, or imagining the interaction from the point of view of the conversation partner.

The authoring tools will use a flow-chart framework that helps children with ASD understand social skills and conversational goals by making the skills explicit. 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 'share' or 'compliment.' A story might, for example, be scripted to start with a 'greeting' object, followed by a 'share idea' 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. Figure 8.5 depicts the authoring of such a story.

The actual intervention is a series of interactions with the system and an adult. First, children interact with the virtual peer to get an idea of what the system does.

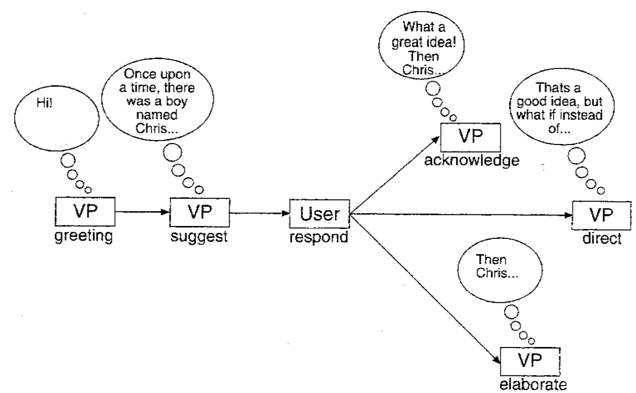

Figure 8.5 Authoring interaction example.

Then children control the virtual peer and choose its reactions. The control mode allows children to rehearse and observe interactions. Children then learn how to create their own stories and behaviors using the author mode by creating storytellers for their peers to interact with. Finally, children share their virtual peers, by controlling their own virtual peer, selecting its responses, while another child interacts with it. These interactions will lead children to go back and redesign their system.

This authoring technique has been used with typically developing children in the Storyteller Agent Generation Environment (SAGE) project, with good success (Umaschi-Bers and Cassell, 2000). SAGE is a storytelling system that enables children to tell stories, find personal relevance in other people's stories, and design and build their own storytellers. Interacting with SAGE empowers children to explore their own identity as well as how they wish to present themselves to others.

The authorable virtual peer casts children in the role of technologists by asking them to program the behaviors of a virtual character. When creating these interactions for the virtual peer, children are constructing their own understanding of the interaction and able to observe the effects of what they program on social interaction. In this way we are providing a scaffold to these social interactions. This process of authoring virtual peers has its roots in the *constructionist* tradition – the use of technology as 'objects to think with' (Harel and Papert, 1991), 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 extending the constructionist paradigm to learning about language and social interaction through building communicating virtual humans.

8.7 Virtual Peer Methodology

The methodology we use to design our virtual peers informs both our understanding of children and the design of our systems. The design of our virtual peers is informed by first carefully studying human behavior. Thus, for the PAT project, first we want to know how the collaborative storytelling behaviors of children with ASD differ from our model of typically developing children's collaborative storytelling. For example, do children with ASD use storytelling roles? What speech acts and turn-taking behaviors do they use?

In this context we are conducting a study to carefully observe and analyze the collaboration skills, nonverbal behavior, and storytelling roles used by children with ASD during an interactive narrative task. We elicit collaborative storytelling from children, videotape children as they tell stories, and then analyze the data. Our analysis is focusing on collaborative speech and turn-taking behaviors (Wang and Cassell, 2003) based on our model of typically developing children, use of decontextualized language (Ryokai *et al.*, 2003), and uses of social skills such as sharing ideas, complimenting others, and recommending changes nicely (Webb *et al.*, 2004). From this data we create a formal model of these collaborative storytelling behaviors in children with ASD. Comparing collaborative storytelling in children with ASD to an existing model of collaborative storytelling in typically developing children (Wang and Cassell, 2003) reveals what needs to be made explicit in the subsequent computer intervention.

As we build the interfaces for our system, we use an iterative design process that relies on prototyping a system and then continuing to revise the design by having children with ASD interact with the system. This allows us to design an interface that is maximally intuitive to the child, and maximally successful.

Finally, we will evaluate the system to examine how children with ASD use the system in each of the modes of control, author, and interact, as well as to measure effects of the intervention. Our evaluation of the treatment will employ a within-subjects design, so that we can account for the individual differences among children with ASD, and a between-subjects design to compare interactions with the virtual peer to: (a) the child's baseline treatment; and (b) interactions with typically developing peers. Within these comparisons, we will investigate whether interactions with the virtual peer improve communication and reciprocal social interaction skills. A pre-/post-test design will specifically target communication, reciprocal social interaction, and theory of mind skills, as well as transfer of communication skills from conversations with the virtual peer to conversations with others.

For the purposes of this project, we are working primarily with children with high-functioning autism (defined as IQ above 80, including children with Asperger syndrome and PDD-NOS) to maximize opportunities for participation from the children and to allow for optimal feedback from the participants. Future work will extend the use of authorable virtual peers to a broader range of ASD.

8.8 Pilot Studies

Our system and studies are still under development. However, we have conducted two pilot studies to evaluate feasibility and design constraints of using virtual peers to practice social interaction. The goals of the first study's pilot sessions were to observe a child with a social skills disorder interacting with a virtual peer system, and then controlling the virtual peer himself; test authoring task ideas; and gain insight into potential technical design issues of the proposed system. The second study investigated verbal and nonverbal behaviors of interaction with a virtual peer through structured observations of a child with Asperger syndrome.

8.8.1 Pilot Study 1: Task and Technical Evaluation

Our first pilot participant was Tom,[1] a 10-year-old boy with a nonverbal learning disorder. The pilot systems we used included the current Sam virtual peer system and an off-the-shelf development environment for talking heads. As described earlier, the Sam system uses prerecorded story segments to collaboratively tell stories with a child, and a complex Wizard of Oz interface to enable an adult to select Sam's responses. The off-the-shelf development environment creates dialog utterances that are then spoken by an animated character. Unfortunately, this development environment did not allow control over the gestures of the talking head, which were automatically selected.

Tom spent one session telling stories with Sam and then controlling Sam. He then spent five sessions interacting with the development environment. His first development environment task was to modify one of the demos that came with the system, and make it complete a task of his choosing. The demo was a pizza ordering system that first asked a question with three choices for an answer, followed by a question with four answer choices, followed by a yes/no question. Tom typed in new dialog prompts for each question that were spoken by the speech-generation feature of the system, and modified the possible answers from the user. Tom modified the system to have an alien/science fiction theme.

Next, Tom spent two sessions developing a dialog system from scratch. This time we used the voice recording features of the system instead of speech generation. Tom enjoyed using a variety of accents for recording dialog prompts. Tom decided to make a system for his father that told him to remember a phrase, and then asked a series of questions. After Tom created several question nodes, he got to the last node. Instead of simply asking the users to say back what they were told to remember, Tom had the system ask, 'What is the penultimate word of the sentence I asked you to remember?'

In the final two sessions, Tom wrote a creative story for his sister using the development system. His story concerned two children who go into a chicken coop that turns into a spaceship. The chickens turned out to be aliens. The children get hungry, and go into the kitchen and discover gray paste that turns itself into whatever you want. After eating, they command the gray paste to turn into guns to fight the aliens. Tom gave the user the option of deciding what the children in the story would do next, and created two different endings for the user to choose from.

These pilot sessions revealed some important design constraints for work with this population:

[1] Names have been changed.

- *Avoid speech recognition.* Speech recognition, with its attendant break-downs, was particularly frustrating for Tom to use.
- *Provide a more structured design environment.* The off-the-shelf development environment, meant for designers of dialog systems, is complex and offers many options that are distracting to the task. For children of this population, a structured sequence of steps for composing utterances facilitates story authoring.
- *Provide flexibility in character design.* The system we used offered several choices of characters. Tom was taken by the ability to choose his character.
- *Enable typing OR speaking dialog segments.* The development toolkit requires designers to type a response for both the speech synthesis and speech recording features. While requiring both for recorded speech is tedious, Tom did indicate that he likes having the flexibility of using either feature.

In general, this pilot indicated the importance of balancing flexibility with structure – allowing the child to design his own personally meaningful stories and characters, while not leaving the task unconstrained. And most importantly, these pilot sessions suggested that controlling and designing a character is an extremely engaging activity, with clear benefits for understanding how social interaction works. At the end of the first session, for example, Tom enthused, 'you can make him say funny things. Plus, normally, you don't get to control people. . .' During a subsequent session, we were struck by Tom's ability to remain focused on the task, his ability to iteratively improve the look and behaviors of his virtual character creation, and his desire to test his creation on his mother, father, sister. . . and anyone who came by the lab. Finally, Tom was clearly quite focused on the full-body behaviors of the virtual peer, and their meaning. At one point, Tom spent considerable time discussing with us whether Sam was a boy or a girl, and as part of his discussion, jumped to his feet and mimicked for us the nonverbal behaviors that the virtual peer demonstrated.

8.8.2 Pilot Study 2: Structured Observation of Virtual Peer Interactions

Our second pilot participant was Mary, an 8-year-old girl attending a school for children with ASD. This study focused on characterizing Mary's interactions with a virtual peer through structured observations of a single session. 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. We transcribed the session and coded Mary's speech for types of collaborative speech acts, and reciprocal social nonverbal behaviors including eye gaze, play gestures with the toys, and head nods. Our goal is to set up a coding scheme that allows us to compare the behavior of children with ASD to our model of collaborative storytelling for typically developing children, and to test that coding scheme on one child with ASD. Behaviors that are different from our model suggest the kinds of interactions the virtual peer intervention can target.

Our model of collaborative storytelling in typically developing children consists of three elements – the roles of collaborative storytellers, their speech acts, and their turn-taking behaviors – and is summarized in Table 8.1 From this model, we focused on the specific speech acts Mary used, assigning one code to each of Mary's turns, and her eye gaze, gestures with the physical toys, and head nods. We then looked at co-occurrences of speech acts with the different nonverbal behaviors. Our codes are summarized in Table 8.2.

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, summarized in Table 8.3, were mainly collaborator-elaborate and response-Sam, demonstrating her ability to, and interest in, listening and responding to Sam. In addition, when Sam asked her to tell a story, she facilitated her own story. 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.

When Mary engaged in a similar storytelling task with another child with autism, she interacted in a manner actually quite similar to her interactions with Sam. The children seemed interested in collaborating with each other, and were able to facilitate and elaborate story segments. Their collaborations were locally contingent, building on each other's utterances. For example, their interaction began with one child introducing one of the girl dolls as herself and another as Mary. Mary responded to her by disagreeing and suggesting an alternate assignment of the characters. This interaction demonstrates that the two children are able to attend to one another's pretend behaviors. However, the two children were less able to collaborate on the construction of a narrative structure together. For example, while they talked about Build-a-Bear in their story, they were not able to fully develop a narrative about Build-a-Bear. Other speech acts, such as 'direct' to propose a storyline about Build-a-Bear, could have been used to construct a narrative goal. Using the technology to elicit different collaborative speech acts will strengthen the potential of a virtual peer intervention and the children's interactions with each other. Role-playing enables children to practice imaginative play, while suggesting, directing, questioning, and acknowledging are all reciprocal social interaction speech acts.

Table 8.1 Taxonomy of children's collaborative speech acts

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

Table 8.2 Collaboration code scheme

Speech acts
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
Response-Sam
Eye gaze
EGToSam
EGToPhysicalToys
EGToVirtualToys
EGToHuman
EGAway
Gestures
Non-narrative
Hold
Move
Examine
Narrative
ChildCharacterSpeak
ChildStoryNarration
SamCharacterSpeak
SamStoryNarration
Head nods

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 8.4. Likewise, during Sam stories, Mary's gaze moved back and forth between Sam and the

Table 8.3 Total count of speech acts performed by Mary

Speech act	Count
Non-story comment	3
Response-Sam	7
Collaborator	
Elaborate	7
Acknowledge	0
Facilitator	
Elaborate	1
Direct	0
Author	
Acknowledge	0
Answer	0
Question	0
Critic	
Answer	0
Question	0
Correct	0
Suggest	0
Co-author	
Simultaneous turn	0
Role play	0

Table 8.4 Summary of eye gaze, gestures and head nods co-occurring with Mary's speech acts

	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 8.5 Total count of eye gaze and gesture co-occuring with Sam's story narrations

	Count
Gesture	
Non-narrative	
Hold	9
Move	5
Examine	8
Narrative	
Child Character Speak	
Child Story Narration	
Sam Character Speak	6
Sam Story Narration	1
Eye Gaze	
To Physical Toys	22
To Virtual Toys	1
To Human	
Away	
To Sam	21

physical toys, which she was using to act out the story that Sam was telling, as illustrated in Table 8.5.

Our results show that Mary engaged with the virtual peer and practiced collaborative behaviors that she also uses in interactions with her real peers. We hypothesize that the virtual peer authoring tools will enable children with autism to practice and construct reciprocal social interactions, and will encourage them to experiment with skills that they are not able to easily use with real peers. The personalizability of Sam is maximized by a design whereby each child is first tested in conjunction with a real peer, so that Sam can then be tuned to work with the individual deficits manifested by that child.

8.9 Current Status and Future Directions

We are currently designing and developing new *control* and *build* interfaces for our authorable virtual peer system as described above. In addition, we are continuing to collect pilot data on interactions between pairs of children with ASD as well as children with ASD interacting with our current virtual peer, Sam. These studies will build on the knowledge gathered in our early pilot studies described above and will further inform the design of our system.

In addition to developing new interfaces for children to control and author virtual peers, this project has also led us to create a new, flexible system for developing embodied conversational agents (the technology underlying virtual peers). This system will provide the framework for coordinating gestures and speech that comprise a virtual peer's stories.

If the authorable virtual peer is successful with high-functioning children with ASD, we hope to extend the work to support individuals in a broader range of the autism spectrum. In addition, we will apply cognitive neuroscience techniques, including cognitive psychology, neuroimaging, and neurophysiology, to understand the mechanisms underlying change in response to interactions with the authorable virtual peer.

8.10 Implications for Designers, Researchers, and Policymakers

Our research holds implications for designers, researchers, and policymakers. By employing new methods in artificial intelligence and computer graphics for designing and implementing autonomous virtual characters, we offer designers an improved method for using full-body virtual characters in their systems. In addition, by creating new kinds of interfaces that are suitable for young children, for children with disabilities, and perhaps in the future for other nonliterate populations, we are advancing the study of human–computer interaction.

Our studies also add to the understanding of ASD itself and to the design of interventions for children with ASD. More generally, we offer new directions for the use of technology to facilitate communication and learning for children with disabilities.

Finally, our research supports the importance of both computers and social skills instruction in the lives of children with ASD. We thus offer support to education policy reform that seeks to provide improved access to these resources for children with ASD and related disorders.

8.11 Conclusion

In this chapter we have discussed the motivation, design, and implementation of PAT (Play and Tell), an authorable virtual peer for children with ASD. Based on research on the triad of impairments that characterize autism spectrum disorder, and how these impairments may be linked to a deficit in theory of mind, we have discussed a set of key features that we believe are important to interventions for children with ASD: (1) a peer context, rather than a virtual parent or teacher, so that children can practice peer social interaction skills; (2) a personally meaningful storytelling task for practicing imagination and language; (3) a system that is authorable by the child, to allow the child to literally build appropriate social skills from the ground up.

These features are instantiated in an authorable, life-sized, full-body virtual peer that uses a peer context and collaborative storytelling task to give children with ASD a space to play with social interaction, communication, and imaginative play behaviors. Children interact with the virtual peer by telling stories with the system, control the virtual peer by selecting predefined responses, and author the virtual peer by creating their own content. Our evaluation of PAT will focus on the effects of the interactions on children's social skills both within a storytelling task and in transfer to other contexts, such as their home.

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