

Dolltalk:
A computational toy to enhance narrative perspective-taking

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Abstract

School curricula are designed with the expectation that students achieve literacy. They usually support the acquisition of language by encouraging students to learn how to decode information within a sentence. In this thesis it is suggested that literacy skills in children five to seven years of age can be obtained with a broader understanding of language and its representation. Oral storytelling is presented as a way to develop meta-cognitive skills with a focus on character-based narrative where children must create the perspectives of the characters. The ability to tell stories is common to children from every community and can help them in school performance. Children should therefore be encouraged to express their understanding of character perspectives in oral storytelling.

This thesis presents a tangible interface that allows children to practice preliteracy skills using oral language. It introduces Dolltalk, a system that facilitates children's ability to take narrative perspectives through the mechanism of reporting speech. The toy presented works by asking children to tell stories and by playing back the stories to the child using narrative features. The ability to express the way the characters think and feel in a narrative and what motivates them to act has been shown to be predictive of academic competence among preschool children. A user study was conducted to understand the short-term effect of Dolltalk on children's elaboration of internal states of story characters. The results show that playing with Dolltalk encourages children to introduce their characters in the story and to express the internal states of their characters much more than with the use of a simple tape recorder. The results also show that playing with the current version of Dolltalk or with Dolltalk in tape-recorder mode encourages children to provide spatial and temporal information in their stories much more than they would without hearing any playback of their stories. This thesis presents significant results ($p = .04$) that indicate the current version of Dolltalk encourages children to express the internal states of their characters.

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To my wonderful aunt Nicole Roberts-Vaucelle,

I would have liked to dedicate this thesis to many of you. But I have a strong reason for dedicating it to one person only: this person is the greatest mentor I have ever had. She is the one who gave me wings to go abroad and be strong. She taught me to forgive people, to go further without feeling any anger.

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Introduction

Motivation

We were a silent, hidden thought in the folds of oblivion, and we have become a voice that causes the heavens to tremble.

Kahlil Gibran

When I was six years old, my sister and I liked to play with a tape recorder. My sister was ten years old and was learning German by practicing with the tape recorder. One day we had this idea to record our poems, stories, songs, and even our game inventions. I remember being really surprised when hearing my voice played back, and I thought the device was somehow changing my voice. We repeated this recording process until we were satisfied with our stories. This game was a very powerful way for me to alter the perspectives I created in my story. It also led to many laughs: "Look what you've said!" By being the creator of my stories, by having a magical record of it, I could actively engage in this imaginary world and change it. I would like all children to feel that they can be part of their own worlds and that they are able to have an impact on them.

I have a dream, that my four little children will one day live in a nation where they will not be judged by the color of their skin but by the content of their character. I have a dream today!

Martin Luther King, Jr.

I also have the idealistic idea that if children can reflect on their actions, and describe the internal states of others, they would be more likely to look at the internal states of their friends rather than their superficial appearance.

For my previous Master's degree in Multimedia (Vaucelle, 99), I built an electronic mail composer for young children to share ideas about perception. The emailer¹ is composed of an audiovisual space where children engage in different visual perception games. Children are immersed in a dream-like universe where shapes guide them along their discoveries instead of the traditional pull-down and contextual menus. By discovering visual correlations and by reproducing them for other children via email, they can reflect upon the aspects of visual

¹ Information about the emailer is online at: <http://web.media.mit.edu/~cati/research.html#emailer>

perception. For my post-graduate degree in Art and Technology (Vaucelle, 00), I built a story generator based on Vladimir Propp's analysis of the *Morphology of the Folktale*. The Story Generator² encourages young children to understand how the structure of fairy tales works by allowing them to create their own narrative elements within this structure. During the process of composing their own stories I was hoping that children would break the rules and create new types of stories.

A story should have a beginning, a middle, and an end... but not necessarily in that order.

Jean-Luc Godard

When I came to the MIT Media Laboratory, I wanted to work on story construction and the manipulation of story structure. I wanted to create a toy that would retell a story from the perspective of someone else. The idea was to have the playback come from multiple dolls, which children could associate with these perspectives. I met another researcher, Tristan Jehan, who offered his audio analysis expertise to help me build a quick prototype of such a system. I made the first version of the prototype in Neil Gershenfeld's "How to make almost anything" class, a seminar that provides a hands-on introduction to resources for designing and fabricating smart systems and covers a large range of topics including design tools, machining, cutting, materials and finishes, molding, electronics, and microcontrollers. The course culminates with a final project that combines the techniques learned throughout the semester (Gershenfeld et al., 00). My system, built as a part of this class, was made with electronics and microcontrollers and built with Plexiglas. I called it "Dolltalk."

This research is founded on the claim that children do not need motivation to learn, because learning is part of their growth process. If children understand that reading or writing is important to communicate with others they will try to appropriate it (Ferreiro, 00). The goal of this thesis is to provide a context for children to express their ideas and skills. Technological toys can facilitate this experience by recording children's stories and then offering them the opportunity to retell them. In the process, it is hoped that children improve with subsequent attempts and can discover by themselves what makes a "good" story.

Dolltalk (Vaucelle and Jehan, 02) is an interface that encourages children to tell and act out original stories. Dolltalk is a toy that simulates "speech recognition" by capturing the physical gestures and speaking voice of a child. Dolltalk does not understand the content of

² Information about the storygenerator is online at: <http://web.media.mit.edu/~cati/research.html#generator>

the child's speech, but through analysis of physical motions and pauses in speech, it can determine whether the child is using: a character voice or a narrator voice. The toy then plays back the pretend-play speech of the child by pitching the voices representing the characters of the story higher or lower. The tangible interface of Dolltalk and its capacity to retell a story enhances the creative ability of children to take different perspectives in narrative elaboration.

Creativity represents a miraculous coming together of the uninhibited energy of the child with its apparent opposite and enemy, the sense of order imposed on the disciplined adult intelligence.

Norman Podhoretz

Overview

This thesis first describes how a five to eight-year-old child might interact with Dolltalk. By defining preliteracy skills, it presents the theoretical framework on which the system is based. The field of emergent literacy is covered and the specific features used by Dolltalk are analyzed to emphasize the role of Dolltalk in enabling children to take multiple perspectives and understand the feelings and thoughts of different characters and their motivations.

Some related research is presented to show how Dolltalk has emerged and how it can contribute to the field of Human-Computer Interaction for children. This thesis discusses the technical issues raised in the design process of Dolltalk with descriptions of the system design and implementation.

The user studies following each version of the system is described. Around fifty children from five to eight years of age have played with the different versions of Dolltalk and have helped considerably to improve the usability of the system.

This thesis presents a discussion about the empirical study conducted using two different versions of Dolltalk. These versions have been designed to determine the effect of each narrative feature of Dolltalk on the storytelling ability of the children. The first version features an Alien that repeats stories like a simple tape recorder, and the second version features an Alien that retells a child's stories by introducing the characters' speeches with a framing clause and pitching the characters' voices higher or lower. The results of the study indicate that there is a significant improvement ($p < .05$) in the child's capability to express the internal states of characters when the version with altered playback is used versus the unmodified playback of a tape recorder.

Finally, some open questions are presented for a new version of Dolltalk and for another possible empirical study that could be conducted for a deeper understanding of the underlying mechanisms in Dolltalk.



End of Introduction

Scenario: a child plays with Dolltalk

Dolltalk is a computational toy designed for children five to eight years old. Its use requires no familiarity with computers. Dolltalk is primarily designed to be played with either at home or at a school. Although it was originally designed for a single child, the system can support two children playing together.



The following scenario is extracted from our final user study described on p.132. The child is first asked to play with an Alien called Tuni, an interaction that will later be analyzed to ascertain the child's level of language use (see p.66 for more details).

The child then plays with a second Alien named Zia who is part of the actual Dolltalk system. In each version of the system, the child has two modular puppets and a puppet theater to play with.



A child playing with Dolltalk

The following scenario between a child and two different Aliens is given as an example to provide the reader with a better understanding of the type of interaction that can occur between a single child and the Dolltalk system

Maria is a six year-old girl who is used to playing with dolls and bringing them to life by telling stories with them. Her teacher proposes that she play with a "special toy." Maria smiles and says that she loves toys and that she is excited to know why this toy is so special. As soon as she approaches the toy, she seems curious to see that it is made with a soft and colorful material. She opens the entrance door of a soft

with a soft and colorful material. She opens the entrance door of a soft purple puppet theater and discovers a stage with two puppets on top of it. Suddenly, a young Alien appears on the other side of the stage.

TUNI: Hello! My name is Tuni; I'm seven years old. I'm here with my friend Zia, and we are really curious about people on your planet. Zia is still in the spaceship, but Zia will come soon. Will you play with these two puppets and show me how kids live on planet Earth?

MARIA: Okay!

Maria grabs the two funny-looking puppets.

TUNI (*enthusiastically*): Ready? Let's go! When you are done just put the two puppets on my hands!

Maria looks excited. She grabs the two puppets and puts them on her hands. As soon as she moves them, their red mouths blink and make a "cute" sound. She touches the head of the puppets, and realizes that everything can come off! She changes the puppets' hair, eyes, and nose. She can create any character she wants. One of the two puppets seems to be her best friend and the other one herself.



MARIA: (*Moving the first puppet*) Hi! Go get some...Let's go pet a dog! (*Moving the second puppet*) Ok, come on. (*Moving the first puppet*) Umm, ummmm, ummmm. (*Moving the second puppet*) The end.

Finally, Maria puts the two puppets back onto Tuni's hands. Tuni immediately moves and starts speaking.

TUNI: That's a good story! Let's do it again! When you are done just put the two puppets on my hands!

Maria stops talking. She plays with the puppets and watches the Alien without saying anything. After 5 minutes Tuni speaks again.

TUNI: I gotta go, but I will be back!

Another Alien appears on the screen behind the stage.

ZIA: Hey! I'm Zia Tuni's best friend! I also want to hear your story! You can play with these two puppets, and maybe you can show me how kids live on Earth.

MARIA: Okay!

She grabs the two puppets.

ZIA: Ready? Let's go!

Maria takes the two puppets and tries different props on them.

MARIA: *(Moving the first puppet)* Yeah! I love to pet the dog. Let's go pet him. *(Moving the second puppet)* Ummm, ummm, little kitty. *(Moving the first puppet)* Oooh. Meow. *(Without moving the puppets)* The end.



Maria puts the two puppets onto Zia's hands. Zia immediately moves and begins speaking.

ZIA: That's so cool, let me see if I understand, do you mean this?
(high voice) **"Yeah! I love to pet the dog. Let's go pet him."**

Then the other one said: *(low voice)* **"Ummm, ummm, little kitty."**

Surprised, one said: *(high voice)* **"Oooh. Meow."**

(normal voice) **The end.** That's a good story! You know what, the most popular game on planet Blooper is to race with yellow stars. Kids love to catch and ride on yellow stars. I'm anxious to hear a story about the most popular game on Earth. Can you tell me a story about your favorite game with the two puppets?

Maria laughs while listening to the story of Zia. Maria quickly grabs the two puppets.

MARIA: *(Without moving the puppets)* Once upon a time there was two friends and they were happy together. So one of them said to the other, *(Moving the first puppet)* Do you want to play? *(Without moving the puppets)* And the other one said, *(Moving the second puppet)* OK.

(Without moving the puppets) And so they went to the park. One of them went on the swing, the other went on the slide. The one, the person that was on the swing, they got hurt. Then the other one went on the swing and picked her up to, to see if she was alright, and she was. The end.

Then, Maria quickly gives the two puppets back to Zia.



ZIA: That's so cool, let me see again if I understand, do you mean this?
(normal voice) **Once upon a time there was two friends and they were happy together. So one of them said to the other. *(high voice)* Do you want to play? *(normal voice)* And the other one said, *(low voice)* OK. *(normal voice)* And so they went to the park. One of them went on the swing, the other went on the slide. The one, the person that was on the swing, they got hurt. Then the other one went on the swing and picked her up to, to see if she was alright, and she was. The end.** Cool! You know kids on planet Blooper love to eat sugar clouds. Kids love to try different flavors of sugar clouds. I'm curious to hear a story about what kids on Earth love to eat. Can you tell me a story about your favorite food with the two puppets?

The child continues back and forth telling and listening to stories with Zia.



This scenario has described the mechanism of an interaction between a child and the Dolltalk system. The following chapters present the implications of such interactions in the field of preliteracy activities.

•
End of Scenario

The exploration of literacy and play activities

Literacy: a challenge

The problem is illiteracy. Its economic costs exceed \$225 billion per year. . . . Its human and social costs are incalculable.

Jack Mostow and Gregory Aist

Even though oral language is our primary system of communication, literacy is crucial in school and on the job. The ability to use the written medium is required to communicate within the current social community. There is therefore a severe disadvantage to be unable to communicate using written discourse. People with low reading skills are much more likely to be unemployed, poor, or incarcerated (NCES, 93). Difficulty in reading is widespread (NCES, 92; OTA, 93) and 69% of fourth-graders have a reading proficiency below the required level (NAEP, 98), and 38% are even below the basic level (Donahue et al., 99) in the United States.

An important challenge in language acquisition is the category of children reared in poverty; their language skills are closer to those of children with mild mental retardation than the language skills of middle-class children (Whitehurst, 97). Furthermore, researchers have observed that many children are not interested in traditional literacy activities (Ananny, 02). A “traditional approach” of literacy involves the observation of how children learn to manipulate the written media (Olson, 77). How then is it *possible to acquire certain literacy skills through interaction with media other than text?* (Ananny, 02).

Many researchers have worked on this literacy challenge, and many have agreed that the mastering of literacy skills is a gradual process that begins a long time before children study literacy at school (Goodman, 86; Sulzby, 96; Whitehurst and Lonigan, 98; Pontecorvo and Orsolini, 96; Kies et al., 93; Garton and Pratt, 89; Pontecorvo and Zucchermaglio, 90). The acquisition of literacy skills must be understood inside of a *growing repertoire of linguistic behaviors* (Pontecorvo et al., 96). For instance, all children can think about writing; if they notice that words are important for adults, they will try to consider them as important for themselves (Ferreiro, 00). Although written discourse can follow different rules from oral discourse, there is not a direct mapping between speaking and writing (Biber, 88), and the

oral and written aspects of language develop concurrently rather than sequentially (Sulzby and Teale, 91).

Researchers have examined the predictive relation between narrative conventions in oral storytelling and academic performance. They have shown that the awareness of narrative conventions in oral storytelling can help children in their reading comprehension (Cameron et al., 88). Indeed, during the preschool years, children usually do not read and write yet, but they explore the conventions of writing in a playful environment. This exploration, called *Emergent literacy* (Teale and Sulzby, 86), will be reviewed in the following section.

Emergent literacy consists of the skills, knowledge and attitudes that are presumed to be developmental precursors to conventional forms of reading and writing and the environments that support these developments.

Grover J. Whitehurst and Christopher J. Lonigan

Emergent literacy from five to seven years of age

The model of emergent literacy proposes a perspective about young children and their reading and writing skills. This perspective stops at the age where the child is able to read and write the way adults recognize reading and writing; this usually occurs when the child is seven-years old. Most research on early literacy acquisition focuses on children aged six or older and concerns *reading readiness*, a state where children can be prepared mentally for reading. This concept comes from a logical analysis of literacy skills from an adult perspective rather than from a developmental perspective. Emergent literacy is more interested in the notion of child-as-creator-of-language (Teale and Sulzby, 86). Researchers have proposed a model of how the different components of emergent literacy develop, influence each other, and influence traditional literacy skills. Researchers have distinguished two interdependent sets of skills that emerge in literacy acquisition: the *inside-out skills* and the *outside-in skills* (Whitehurst and Lonigan, 98).

The inside-out skills represent a direct understanding of the rules of language. For instance, for decoding written language children need to be able to make a link between the sound of a letter and its symbolic representation. The outside-in skills represent the understanding of how language works in a given context by considering the conventions associated with reading and writing, one elementary example is pretending to read by looking at a book from right to left and scanning

from up to down. A more advanced example is adapting one's speech to a given listener's context.

The distinction between pre-reading skills (*inside-out skills*) and conceptual skills (*outside-in skills*) is necessary to understand how emergent literacy influences children's literacy learning. Research has shown that having larger vocabularies helps four to five-year-old children read because they can recognize more letter combinations (Whitehurst and Fishel, 01). However as they get older, it doesn't help them as much because literacy learning is not so much about decoding written information as it is about how language works in a particular context (Snow, 83). Therefore from five to seven years of age, children need to practice their outside-in skills.

The research presented in this thesis is concerned with the outside-in skills as part of a cognitive and social process. The interface that is proposed for children, Dolltalk, is meant to encourage children to reflect on language at a conceptual level. Children are stimulated to specify the perspectives of their characters in their narratives (*see p22*). The following is a review of the components of both inside-out and outside-in skills of literacy.

Inside-out-skills

Inside-out skills are concerned with the phonological and syntactic awareness and the grapheme-phoneme correspondence (Ryokai, Vaucelle, and Cassell, *in press*). They facilitate the ability of children to decode information within a sentence. This is important for four to five-year-old children, because they need to learn for instance how to decode letter names (Whitehurst and Fishel, 01).

Knowledge of graphemes and grapheme-phoneme correspondence

Graphic awareness is the ability to distinguish letters and recognize the existence of letter names (Lomax and McGee, 87). The knowledge of graphemes is the ability to name the graphic symbols of the alphabet by distinguishing, for instance, A from B from C. For example grapheme-phoneme correspondence skill is knowing that the letter "B" makes the sound [b]. At entry into school, the knowledge of the alphabet is one of the strongest predictors of academic performance (Stevenson and Newman, 86; Lonigan et al., 99).

Phonological awareness

Phonological awareness is the ability to identify the sound structure of words. Phonological awareness is the most important factor considered

in literacy development (Blachman, 84; Wagner, 86). Researchers have studied the relationship between the ability to segment words into phonemes and learning to read and spell. A variety of tasks have been studied: for instance, the presence of a sound in an utterance (Marsh and Mineo, 77), the ability to find rhyming words (MacLean, Bryant, and Bradley, 87; Goswami and East, 00), and the ability to count phonemes (Tunmer and Nesdale, 85). However, becoming literate *cannot be reduced to the learning of a code* (Vernon and Ferreiro, 99).

Outside-in skills

Outside-in-skills represent the knowledge of how language works in a particular context; this is often called metalinguistic awareness (Gombert, 92).

Metalinguistic awareness is the ability to manipulate and reflect upon the written language (Justice and Ezell, 01). For instance, pretending to read is an emergent form of reading. Previous research shows that children acquire metalinguistic awareness at the age of four or five. Later on, they learn to play with words, realizing that certain words, phrases, or sentences can mean different things in different contexts. More specifically, the ability to reflect on language can lead to the understanding that language production affects the person who performs it by reporting, characterizing, and commenting on speech (Lucy, 93). Assisting children in language expression and then encouraging them to think about it is a way to support metalinguistic awareness (Vaucelle, 01). Thus, encouraging children to use their ability to reflect on their stories by specifying the perspectives of their characters is one of the main motivations of Dolltalk (*see p57*).

Written language awareness concerns preschool children's ability to understand written conventions (Justice and Ezell, 01). It is considered the first stage of reading development (Chall, 83). The following sections describe examples of written language awareness.

Print awareness

Print awareness is the understanding of printing and book-reading conventions (Chaney, 92) as well as the ability to interact with and "decode" printed language (Lomax and McGee, 87). For instance, knowledge of print directionality (e.g., from left to right) and the sequence of pages in a book (e.g., front to back) is an indication that children understand print conventions.

Word awareness

Word awareness is the ability to understand that words are different than letters and that letters make up words (Lomax and McGee, 87).

Children do not develop the components of inside-out skills and outside-in skills independently from one another (Lonigan et al., 99). Furthermore, children's outside-in skills (e.g., written language awareness) and their acquisition of oral language skills are also interrelated (Chaney, 92). This metalinguistic awareness is reflected in the telling of stories where spatial and temporal information is provided (i.e., decontextualization). In the following section, I examine how the knowledge of language rules in telling stories can be useful in developing children's reading and writing skills.

Literacy and oral storytelling, a link?

Why should I write when I can tell?

Edith Ackermann

Overview

In 1898, Iredell wrote about the relationship between the development of oral and written skills in preschool children (Teale and Sulzby, 86). Researchers working on either the inside-out skills or the outside-in skills of literacy have all shown that the knowledge of oral language plays an important role in learning how to read and write. However children need to understand why the written medium is important and why communicating in writing is important, especially when they are good at communicating but not good at writing.

The context in oral and written stories

Decontextualization is the language without reliance on spatial or historical context.

Kimiko Ryokai

Children naturally tell a story assuming a particular context. Young children may say, "That animal was sleeping there." However the listener needs to know who "that" is and where "there" is to understand the story. Children have to learn to provide a context in their oral stories by being explicit about where and when the action occurs (Richard and Snow, 90; Snow, 83). The process of decontextualization is a common point between oral and written forms of narratives. In oral storytelling, teller and listener may share a physical, social, or

historical context in understanding the story. In written stories the writer and the reader do not usually share all of this information so the writer has to provide it. The ability to make the transition from contextualized stories (“It’s happening here and now”) to more decontextualized ones (“It’s happening in the park and at 4 o’ clock”) has been shown as a predictor of later literacy (Peterson and McCabe, 94).

However, a study made on children talking on the phone has shown that children were not simply decontextualizing their narratives but were also considering the listener’s knowledge by adjusting their speech (Cameron and Wang, 99). This adaptation has led to the term recontextualization; it requires the teller to proactively take a different perspective to accommodate audience knowledge (Cameron et al., 96). Because literacy is *the ability to communicate with an audience that is in a different space and a different time* (Wells, 81, cited by Ananny, 01), recontextualization in oral stories is a skill that is used for written ones.

Taking a narrative perspective

Our ways with words (oral or written) are the same nature as our ways of understanding and acting on the material and social world. Reading the word and reading the world are, at a deep level, integrally connected- indeed, at a deep level, they are one and the same process.

James Paul Gee

Overview

Gee explains that literacy instruction must be *rooted in the taking and imagining of diverse perspectives on the real and imaginary material of social worlds* (Gee, 01). Similarly in oral narratives, young children not only express their understanding of characters’ perspectives by mentioning for instance the characters’ beliefs, they also take into consideration the presence of the listener by adapting their speech accordingly. If the child fails to understand that the listener has a different point of view on the story, the listener will be unable to follow it. Reflecting on what they have conveyed can help children maintain story coherence and clarify the feelings of the characters.

Maintaining coherence in storytelling

Controlling reference points in a narrative is challenging because it requires children to integrate knowledge across linguistic, social and cognitive domains (Hemphill, et al. 91). One narrative aspect that contributes to coherence is a clear introduction and appropriate

references to characters. Another way to maintain narrative coherence is by giving information about the context. For example when children tell a story on the phone, they compensate for the physical distance by adapting their speech so that the listener can understand the context (Cameron and Wang, 99).

Repetitions

Repetitions can emphasize aspects of a story that are particularly important by repeating certain details, e.g., “It’s a long, long, long, way.”

Perspective shifting

Perspective shifting is the ability to indicate the perspective of different characters in consecutive events. For example, “The frog jumped into the saxophone. The musician couldn’t play.” The shift from the musician to the frog is a perspective shift appropriate for the narrative abilities of a three to four-year-old child (O’Neill and Pearce, *in press*).

Quoted speech

Quoted speech is the use of direct speech with a *framing clause*, e.g., “Then she said, ‘Oh no!’” and indirect speech with a framing clause, e.g., “He said that he wasn’t hungry” (Hickmann, 93). Quoted speech can also be noticed in the use of *voicing*, i.e., the use of different voice pitching, to refer to different characters (Wolf, 89).

Framing clause

The process of framing only helps maintain coherence if speakers adequately specify the intended characters. If two male characters are present, “he said” won’t help maintain coherence, however if the child refers to them by name, e.g., “Paulo said...”, the child has clearly specified the identity of the speaker.

Voicing

Speakers use prosodic intonation and voice quality techniques in reported dialogue to contextualize their point of view (Guenther, 99). It helps clarify to a listener which character is being talked about.

Emergent literacy and play activities

Researchers have distinguished various types of play and how they relate to early literacy acquisition (Roskos and Christie, 00).

A cognitive approach to play and literacy

Cognitive perspective concerns the mental processes in which play and literacy activities may be related. One example is the ability to think about and use language to make sense of experience.

Dramatic play: The connection between toys and literacy

Children connect books to play by utilizing related props. The toys are held as the child reads, serving as realistic representations of characters (e.g., dolls) and actions in the book. The toys are here to create a physical link between the actual reading material and the personal experiences of the children. Research has shown that toys and props can make learning how to read and write more concrete and facilitate children's ability to create a bridge between their world and the conventions of literacy (Rowe, 00).

An ecological perspective of play and literacy

An ecological perspective concerns play and literacy as part of an environment. It looks at ways in which children's environments facilitate engagement in literacy activities.

Educational play

Research has shown that literacy-educational play, for example, the invention of spelling and exposure to printed material, is a powerful way to affect emergent literacy in which not only play serves literacy, but in which literacy serves play as well (Johnson, 00).

The sociocultural perspective of play

Vygotsky explains how play is important for a child's development of cultural awareness and their participation in it. Make-believe play is a way for children to share their experiences with others while incorporating cultural awareness in their stories (Vygotsky, 78).. In sociodramatic play, children imitate what happens in their lives and shape these events into characters, settings, and stories. In the thematic fantasy play, children create an experience that does not exist in the here and now (Piaget, 62).

Dolltalk's investigation in preliteracy activities

Internal states

Dolltalk is designed to encourage the use of *narrativity* (De Temple et al., 91), the ability to elaborate a character's emotional and physical state and to reference their internal thought processes.

The internal states of characters can either be described in terms of **mental state verbs**, which explicitly tell the listener about the intentions and feelings of the character, e.g., "He *likes* playing with puzzles," or by the **mention of mental states**, which includes intentions, cognitions, perceptions and desires, e.g., "The girl was *upset* not to go to her friend's birthday." A subset of mental states is the expression of **belief states**, a more advanced level of understanding character perspectives, e.g., "The boy *thinks* it is better to play in the park." It has been demonstrated that feedback can help children improve their usage of belief states (Slaughter and Copnik, 96).

Quoted speech

Dolltalk is designed to encourage children to specify their story characters by quoting them.

The two different types of quoted speech include direct speech with a framing clause, e.g., "Then she said, 'I want a puppy,'" and indirect speech with a framing clause, e.g., "She said that she wants a puppy."

Spatial and temporal expressions

In comparison to other narrative studies with a technological system (Ryokai, Vaucelle, and Cassell, *in press*), the user study of Dolltalk investigates how it can support preliteracy skills such as temporal and spatial expressions. Spatial expressions are information about *where* an event took place and temporal expressions are information about *when* an event took place (Peterson, Jesso, and McCabe, 99).



End of Exploration

Related research

The most beautiful thing happened on Tuesday night. I was babysitting for Colum, Jenny's little boy, he's 5 (and three quarters!). We made up 2 new super heroes Lava Man and the other Lava Man! We were just having a really good play with lots of jumping around and shouting. Anyway, later we were just sitting down and talking more quietly. He was showing me this little dinosaur that has tiny batteries inside and when you open his mouth he roars. Colum said the batteries were wasted and I said I can get new ones for him. He said 'no, its terrible when the batteries work because every time he opens his mouth all he can do is roar, even when he tries to eat something all he can do is roar so he can't even eat anything so lets leave him with the wasted batteries, he's better that way'. All I could do was smile the widest smile.

Andy Brady

Traditional toys such as puppets and dolls encourage young children's storytelling in the form of pretend play (Singer and Singer, 92). Unfortunately, the majority of technological toys today do not provide the space for children to tell their own stories; rather they tend to tell stories to them or constraint their play pattern. However, children can gain from the opportunity to create stories not just listen to them. They can further benefit from telling stories to a critical audience who can provide feedback. Recently the concept of providing *storyspaces* to support children's storytelling has received significant attention (Bransford et al., 92; Cassell and Ryokai, 01; Ananny, 02).

The quote from Andy Brady stands as an example of how technology can be useless and, worse, annoying or constraining to the child. In this example, technology is not contributing anything to the play pattern of the child except the repetitious dinosaur roaring, and the child in this example voices his complaint by asking not to use this technology anymore. In my work, I aim to add technology to the play pattern of a child in a way that allows the child to be an active participant in story creation. Technology should prompt the child's output, giving feedback or even being clever in how it interferes with the child's play. As opposed to working on storytelling systems (i.e., systems that tell

stories to the child), I prefer to work on *story-listening* systems (i.e., systems that listen to the child).

The following section lists some past work on story-listening toys that have inspired the creation of Dolltalk.

Research on story-listening toys

Storymat

By offering stories recorded by other children who played on the mat at another time, Storymat seems to offer a place for a child to experience collaborative storytelling regardless of the presence of a co-temporal and co-spatial playmate.

Kimiko Ryokai

Storymat (Ryokai, 99) is a story-listening space consisting of a soft mat marked with patterns of houses, roads, rivers and stuffed animals. The system tracks the position of the stuffed animals as the child plays on the mat and records the stories. When a child listens to a peer's story, virtual stuffed animals are projected onto the mat, linking the original play motions to the oral story. The objects appliquéd on the mat work as "story starters" for children and are initially partially determined and eventually transformed into many different objects (e.g., a square shape can be a house or a restaurant).



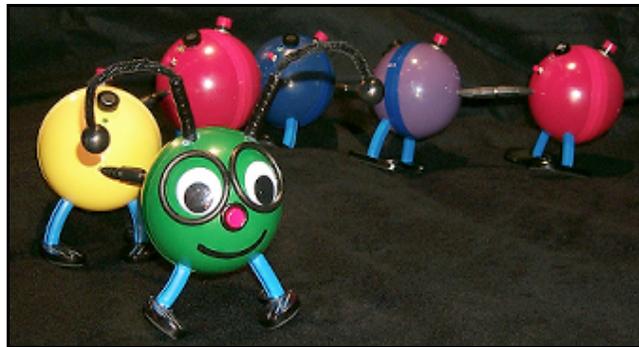
Empirical research with preliterate children playing on Storymat has shown that their stories became richer when they listened to and incorporated elements from peers' stories.

Telltale

By developing new toys that support children's natural language play, we may be able to show how technology can both support and enhance children's pre-existing behaviors.

Mike Ananny

TellTale (Ananny, 02) is a toy made of caterpillar segments. Each segment can record a part of a preliterate child's story. The child puts the pieces together and hears the story organized in the order chosen.



Through colored and communicating caterpillar parts, the child organizes the structure of the story with a beginning and an end using narrative connectors (e.g., and, then) between each piece. Empirical research conducted with TellTale has shown that children tell longer and more cohesive stories with a multi-segmented TellTale than with a unified TellTale (i.e., caterpillar with only one segment).

Animal Blocks

The goal is to encourage children to transfer their oral storytelling, using toys such as Animal Blocks, into written representations, making a connection between children's oral storytelling play and their literacy activities.

Kimiko Ryokai

Animal Blocks (Ryokai, 02) works as a sketch book for children's stories. Children can collect and connect their narratives in collaboration with others.



Animal Blocks consist of tiny wooden figurines representing either animals (pig, fox, bird) or natural elements (tree, water) and a book. Children can write and record stories in the book by moving the blocks in a play space and typing in additional text with a keyboard. The “magic” book plays the stories back and while projecting the recorded text and images representing the blocks onto the book. By flipping the pages of the book, the child can both watch and listen to other peers’ stories.

Touching Tales



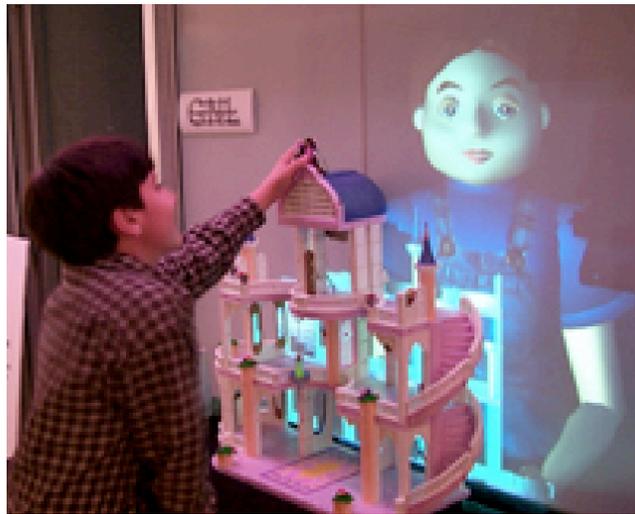
A screen shot of the Touching Tales interface

Touching Tales (Oakley, O’Modhrain, et al.; 02) works by asking children to create stories and providing physical feedback via a vibrating joystick. The young child manipulates different visual elements in the story and receives coherent physical responses from the machine. In the first version, a cartoon character represents the perspective of the child; in future versions, this perspective can switch to another (for example, a rose’s viewpoint) if the character touches it. This provides an excellent device for children to reflect on the thoughts of others. Touching Tales can enhance children’s understanding of multiple perspectives.

Indeed, Selman’s model has shown that from four to nine years of age, children are not able to fully understand and appreciate the motivations and feelings of others (Selman, 81). They do not believe that their perspective and the one of their peers are equally important, and this leads to conflicts. Research has also shown that adolescents who are good at understanding social perspectives tend to be skilled at making friends (Vernberg, et al., 94).

Sam

The Sam system is made of two parts: the character Sam, an embodied conversational agent who looks like a six-year-old child, and a toy castle with two figurines. Sam's appearance is meant to be androgynous so that both girls and boys could relate to it. Sam is projected onto a screen behind the castle and can both listen to a child's stories and tell its own. The figurine can exist in either the physical world or on the screen, so that Sam and the child can pass it back and forth between their worlds.



Empirical research with Sam (Ryokai, Vaucelle, and Cassell, 02) has shown that Sam became a partner for children modeling their own stories. By listening to Sam's stories and having Sam as their listener, children became both active storytellers and critics of others' stories.



The PET robot prototype



Summer, a Diva Starz™

Pets

The Personal Electronic Teller of Stories (Druin, at al., 99) allows children to create stories and to attribute emotions that are part of the story to a robot embedded in a stuffed animal. The robot is not an audience, but rather a representation of the child's perspective.

Mattel Toys: Diva Starz™

Diva Starz™ (Mattel, 01; 02), is a doll whose head moves, eyelashes bat, and lips light up as she talks. The doll talks about music, style, and fashion. Children can press her “yes” and “no” buttons to answer her questions. She knows how you dress her up and when you are touching her head. She has a strong “personality” and can even whistle, pretending to be bored. This doll has over 1600 phrases. When two of them are placed in front of each other correctly, they can talk to one another. While Diva Starz™ is a real success because of its embedded electronics and sensors, it still provides a very limited play pattern for children.

Leapfrog Toys

Leapfrog is an educational toy that promotes literacy through play activities.

Read and Sing Little Leap®

Read and Sing Little Leap® is a toy for children three to eight years of age that teaches colors, phonics, vocabulary, and the alphabet. The toy consists of a plush character with an alphabet storybook.



The character sings two learning songs and features three learning games that encourage children to explore letter names and sounds. The child presses the music button to hear the “ABC” song and presses the letters to hear their names and phonemes. The twenty-six-page storybook helps build vocabulary, and three learning games teach the alphabet and phonics.

□

The LeapPad® Learning System

The LeapPad® is a family of products designed to teach reading skills for children ranging from pre-readers to more advanced learners who are developing reading fluency. LeapPad® Learning System works by placing a book on the LeapPad®, popping in a corresponding cartridge, and touching any page with the “magic” LeapPad® pen. This allows the child to hear words and stories read out loud, to learn letter sounds, to hear colorful characters come alive, and to play learning games.



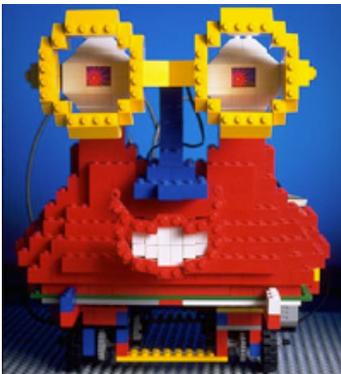
The LeapPad® learning system comes with a thirty-two-page interactive book featuring stories from Richard Scarry and Disney's Winnie the Pooh.

Genuine Object Oriented Programming

Building in the real world still offers a much richer multi-sensory experience than any purely computational world.

Rich Borovoy

Genuine Object Oriented Programming (GOOP) is an integrated physical and computational construction kit in which children can use “Things That Think” technology to build interactive communities of computationally augmented objects (Borovoy R., 96).



Dr. Lego Head

GOOP provides an environment for children to explore their own *theory of mind* (Astington, et al., 88), allowing them to construct powerful ideas about the nature of metaphor and shared understandings. GOOP addresses the following question: can a constructionist environment (i.e., an environment designed to provide students with the appropriate physical and computational materials to construct for themselves a set of powerful ideas (Papert, 91)) be built that allows students to reflect on and expand their own theory of mind?

GOOP makes this exploration accessible and engaging by enabling students to create and participate in physically instantiated “interactive fantasies” involving multiple characters, objects, and places.

Modular toys

The modularity of the puppets in Dolltalk is an important feature based on existing toys. Modular toys usually allow a child to create specific characters using different props (head, nose, ears, legs) or even draw the face of a character with the help of predefined patterns.

Hasbro toys: Mr. Potato Head™



Mister and miss Potato Head™



Mr. Potato Head from the movie Toy Story.



Mister Potato Head™ can be a fisherman

Perhaps the most famous modular doll of all, Mr. Potato Head™, arrived on the scene in 1952. The doll comes with plastic ears, noses, and mouths and can be transformed into any character the child wants to build.



An other transformation of Mr. Potato Head™

A year later, Mrs. Potato Head™ arrived...



Various CD-ROMs with Mr. Potato Head™ exist in which children can play with digital representations of features.



Mattel: What's her face?™

What's her face™ is a fashion doll that lets children create a very unique look. With expression stampers, markers, and glitter stickers, children can give the doll different facial features and expressions. For an additional creative change, each doll comes with two wigs in fun colors and different styles plus fashion accessories that are completely transformable.





What's her face™ doll

Mattel also has created a freely accessible web site that allows girls to create their own dolls on-line.³ Different CD-ROM versions exists as well.



³ <http://www.whatsherface.com/>

Manhattan Toy: Morphing Maggie™ hand puppet

Manhattan Toy has created many hand puppets for children. One of them, called Morphing Maggie, is modular. Children can create a variety of characters by attaching hook-and-loop pieces to Morphing Maggie. A modified version of this hand puppet has been used for the final design of Dolltalk.



End of Related Research

Dolltalk design

Overview

In order to give the child the impression that a character is listening to their stories, I have invented a clever mechanism that captures the motions and speech of a child using sensors and speech detection. Continuing in the vein of research on story-listening toys, I built Dolltalk with the help of Tristan Jehan to encourage children to tell and act out original stories (Vaucelle and Jehan, 02).

Dolltalk consists of two dolls and a system that records and plays back the stories. The playback alters the pitch of the child's voice higher or lower depending on which doll is supposed to be speaking. Children play with their customized dolls and tell their stories, which are recorded and played back with the same content but with different voices. Dolltalk gives the illusion that it can truly listen by analyzing their physical gestures and speech.

The latest version of Dolltalk is a toy with modular puppets. Children create the right look for their characters and use the props to guide their stories (e.g., the character says, "My nose fell off!" and the child physically removes the puppet's nose). The playback is altered in such a way that the child's original voice is unrecognizable. The toy plays back the pretend-play speech of a child in two distinct voices, representing the characters, as well as the actual voice of the child, representing the narrator.

The tangible interface of Dolltalk and its ability to retell a story enhances the narrative elaboration of a child (Vaucelle, 01). Because children can detect inconsistencies in a story told to them (Peterson and Marrie, 88), they will be critical when listening to their own stories retold to them in somebody else's voice. This can help them elaborate upon their original stories in a more consistent and detailed way. This chapter reviews the three different versions of the system that have been built. At the writing of this thesis, around fifty children between the ages of five and eight have played with the versions of Dolltalk described in this document.

Dolltalk version 2000

Description

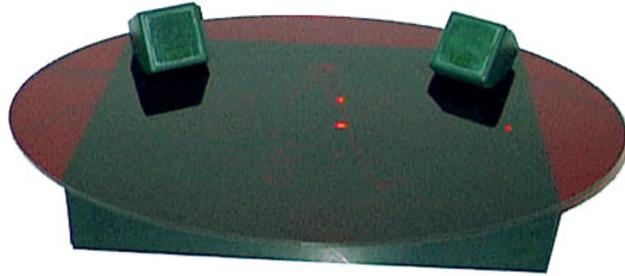
Dolltalk 2000 is composed of a platform with tag sensors, two small speakers, one microphone, a real-time sound analysis and processing software application, and two stuffed animals with accelerometers attached to them. Recording begins when a child removes the two stuffed animals from the platform. Playback is initiated when the two stuffed animals are returned to the platform.



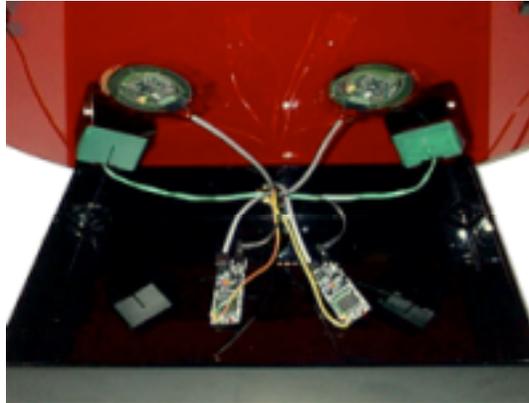
A preliminary study showed that children naturally and unconsciously move the dolls and stuffed animals representing the characters during an enactment of dialogue (Vaucelle, 00). Dolltalk is based on this observation. Since no accurate speech recognition for children exists today, the combination of motion and the presence or absence of a speaking voice are used to determine which stuffed animal's dialogue is being quoted. The system only records when child is speaking. The sentences are segmented and indexed according to the motion of the stuffed animals. The segmentation is done by analyzing the embedded accelerometer signal combined with sound level detection. The computer thus knows which stuffed animal is supposed to be speaking and keeps track of the timing of the sentences. Transformation of the voice is done during playback by pitch shifting and using additional sound processing techniques. If no motion was detected, the system assumes that the child is simply narrating and plays back this part of the speech with an unaltered voice.

Hardware components

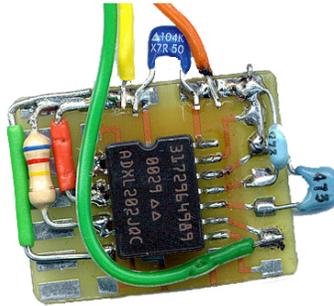
The Dolltalk 2000 stage is built with Plexiglas.⁴ When children want to hear their stories replayed, they put the two stuffed animals in front of two green speakers.



Two tag readers are hidden under the two speakers to detect the presence and absence of the stuffed animals. The playback and sound panning of the two voices is done so that the sound seems to come from the stuffed animal itself. All of the electronics, including sensors which track the children's motions, are placed under the stage or in the stuffed animals in an unobtrusive way.



⁴ The stage is made by first drawing a model using the Coral Draw software and to finally cut a physical model of it in Plexiglas with a Laser Cutter.



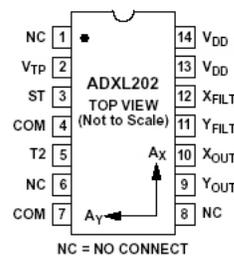
One accelerometer built for Dolltalk

Two accelerometers detect the hand motions used by children when playing with the stuffed animals. They are designed with the ADXL202.⁵ This low cost acceleration sensor measures movement on two axes, but for Dolltalk, only one axis is used. Although it measures static acceleration such as gravity, it was essentially used to measure dynamic acceleration for detecting vibration. The ADXL202 outputs digital data and therefore does not require an A/D converter.

The final circuit design for the accelerometers is less than 9 cm²—small enough to be hidden inside the stuffed animals.

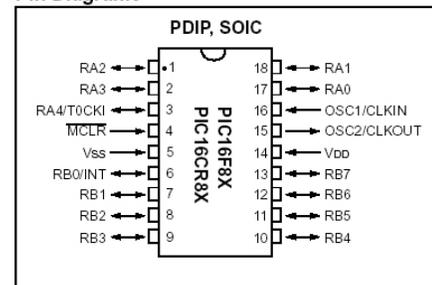
The low-cost CMOS 8-bit PIC16F84 microcontroller measures the data coming from the accelerometers.⁶

PIN CONFIGURATION



ADXL202

Pin Diagrams



PIC 16F84

⁵ The data sheet of the device ADXL202 can be found at:

http://psas.pdx.edu/psas/Resources/DataSheets/Accelerometer/ADXL202_a.pdf

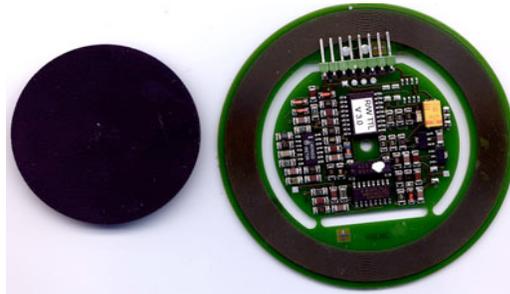
⁶ The data sheet of the PIC16F84 can be found at: http://robostuff.com/dprg/ralph_tenny/30430c.pdf



The iRIX Board

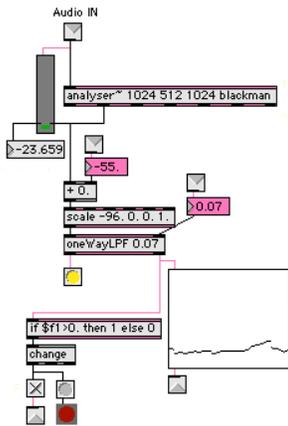
The PIC is mounted onto an iRIX board (Poor, 99) which has a serial connector. Firmware written with MPLAB⁷ for the PIC microcontroller⁸ collects data from the accelerometers and directs it to the serial port.

Two read-write multireaders from Easy Key⁹ detect the presence of the two stuffed animals on the stage. A multireader consists of a tag reader and a RFID tag. One tag is located inside of each stuffed animal and the readers are hidden under the stage.



Software

Real-time software to analyze sound (i.e., the child's voice) and sensor data (i.e., from the accelerometers and tag readers) has been written to index the sentences of the story, and to control recording or playback. The software was written in the Max/MSP environment and runs on a G4 Macintosh computer.



The recording manager of Dolltalk

When the dolls are not on the stage, the software goes into recording mode. A loudness curve is estimated and the audio is band-pass filtered to avoid any extra environmental noises which might affect the child's voice. The sound is segmented into sentences by carefully measuring pauses between words. A fast succession of short words will more likely be part of the same sentence. As the segmentation does not have to be in absolute real time, a new sentence is added to the database a few hundred milliseconds after it was reliably detected.

⁷ Microchip internet link: <http://www.microchip.com/index.asp>

⁸ The PIC has Flash program memory to allow it to be used for prototyping and production. In-circuit reprogrammability allows the code to be updated without the PIC being removed from the end application. This is useful in the development of many applications where the device may not be easily accessible, but the prototypes may require code updates

⁹ The data sheet of the read and write multireader used in Dolltalk can be found at the following Internet address. However it is written in German: http://www.produktinfo.conrad.de/datenblaetter/100000-124999/117005-an-01-de-Easy-Key_RIW_TTL_Multireader.pdf

The two accelerometer-power energies are simultaneously calculated. The total energies for the duration of a complete sentence are compared and a flag (i.e., 1 or 2) is associated with the indexed sentence based on which character is most likely speaking. If no meaningful energy was measured from the accelerometers, then none of the characters are likely to be speaking and a different flag (i.e., 0) is associated with that sentence.

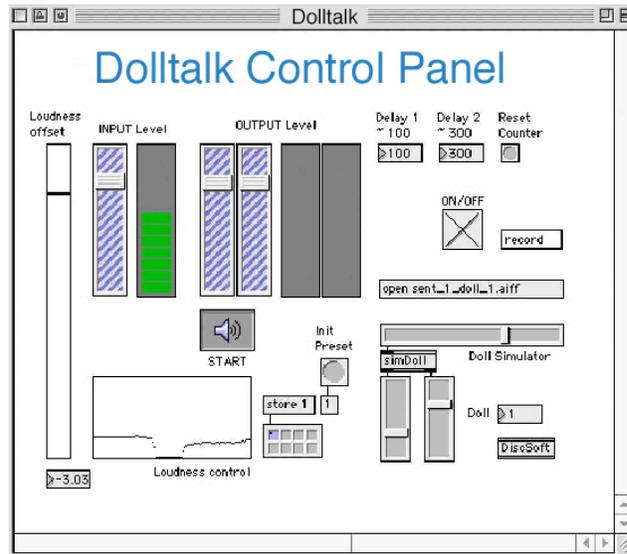
The system differs from a normal tape recorder in that only sounds with silences discarded are stored in memory. The current system stores the audio and associated data (index number, flags, start and stop times for each sentence fragment) in memory; this memory is reallocated at the beginning of each story. However the system can optionally store these in a file, allowing for additional post-experiment studies, or for playing back a story at a future time.

When the dolls are detected on the stage, the system goes into a playback mode. It reads the indexed data and plays the audio back through the speakers. The flag number associated with the sentences allows the software to pan the audio left or right and pitch the voices high or low accordingly. Since the dolls have their own distinct tags, the correct panning and voice alterations are always bound to a particular doll whether placed on the left or right. At playback, silences are ignored and transformed into short pauses.

Reliability of correct sentences segmentation is key. However it is not critical if a sentence is cut incorrectly into several chunks as long as the correct accelerometer flag is associated with it. Optimal results are obtained when the microphone is placed close enough to the child's mouth and the environment is reasonably quiet.

Tristan Jehan,¹⁰ an expert in sound processing, helped with the audio analysis aspects of Dolltalk. His DSP objects (e.g., `peqbank~`, `analyzer~`, `smoother~`) are written for Max/MSP, and are used in Dolltalk.

¹⁰ Tristan Jehan has built many objects for Max/MSP. You can download them at: <http://web.media.mit.edu/~tristan>



Pilot study

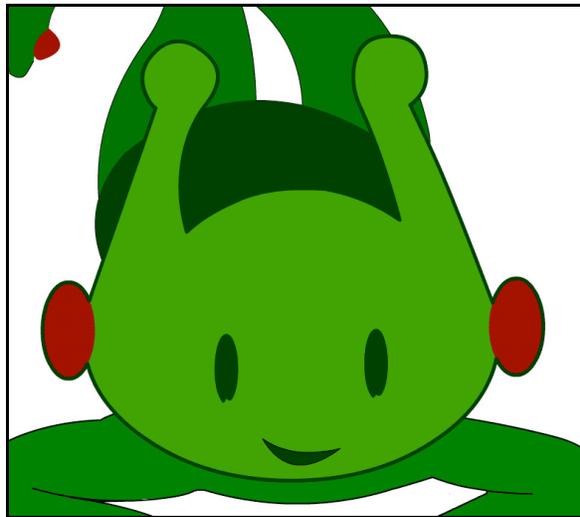
A pilot study with twelve children at an elementary school in a suburb of Boston explored how five-year-old children interact with Dolltalk 2000. This first version featured two stuffed animals: a lion and an elephant. The children worked in pairs. Although no empirical data was collected at the time, they appeared to enjoy their interactions with Dolltalk. They frequently repeated the playback and asked where the voices were coming from, remarking that someone must be in the room listening to them. This illusion of “speech recognition” seemed to encourage the children to be objective about what they were listening to during playback. One of the children repeatedly said, “Who said that? I never said that!”

This user study suggested changes that helped us improve the next version of Dolltalk. Although children enjoyed the activity, they needed an audience as a focus for their storytelling as well as a guide through the interaction. In addition, it appeared that the use of stuffed animals contributed to the construction of less imaginative stories (stories revolving around a lion and an elephant), suggesting that the use of less well-defined dolls would encourage children to be more creative. These features were incorporated into Dolltalk 2001, and an empirical research study was conducted to learn more about their implications.

Dolltalk version 2001

Description

Our recent research on technological toys showed that the presence of a virtual peer significantly increases the child's use of advanced linguistic expressions and helps the child focus on storytelling (Ryokai and Vaucelle, and Cassell, *in press*). For Dolltalk 2001, a story-listening agent standing in as a virtual peer was incorporated into the system. A computer monitor serves as a display for an animated 2D Alien. This youthful Alien guides children through their interactions with Dolltalk. A recent study successfully used a puppet acting as a “naïve” listener. The “naïve” aspect of the puppet’s behavior motivated young children in their storytelling (O'Neill and Pearce, *under review*). Similarly, the Alien tells the children that it wants to hear about Earth so that they have a goal for their storytelling. The Alien uses the “junior” voice from the Macintosh speech manager.



Because children often use story elements (e.g., characters and settings) to organize their narratives during dramatic play (Walker, 99), the Alien asks the child to dress up the dolls and tell stories about them. The dressing-up of the dolls and their physical representations invite children to think about the characters in their story. The process of dressing up the dolls allows them to revise their ideas and to focus on the aspects of the story they really care about. This cognitive process enhances the coherence of the storytelling.



Hardware and software

The hardware is the same in this version as in the previous one, however the placement has changed. Two accelerometers to detect motion are located on the hands of the dolls. The RFID tags are placed inside and at the bottom of the dolls. The RF readers are placed under the Alien's hands, close to the speakers, and the rest of the electronics are hidden under the stage.

The computer is still connected to the iRIX interface, however the keyboard is hidden under the stage and the screen, disguised by a soft, brown, felt material, sits at the back of the stage.

The software was changed in this version. The data analysis part of the code filters the errors coming from the hardware. Also added is the computer animation of the Alien, which talks to the child and plays back the stories.



Pilot study

During a pilot study with seven children visiting the MIT Media Laboratory, the children clearly enjoyed playing with the modular dolls and dressing them up. The children were more engaged in telling their stories, organizing their narratives, and creating their own characters using this version of Dolltalk rather than the previous one. Children were more focused on structuring a complete story rather than creating simple dialogues.



During this pilot study, different limitations of the system became evident. An eight-year old remarked that Dolltalk “lets your story be free, then it is hard and challenging.” All the children requested information about the Alien's life. They seemed to want more guidance through the interaction and seemed to expect more prompting from the Alien. Children also found the computer-generated voice of the Alien annoying after a while. Furthermore, the interpretation of the accelerometer data did not allow the system to be specific about the kinds of motions the child was making. In other words children would move a doll even if its respective character was not talking—for example, if it was supposed to be walking. The accelerometer doesn't differentiate between these two types of motions. If the system cannot tell whether the child intends to make the doll walk or talk, then it cannot parse the audio input accurately.

Dolltalk version 2002

Description

Dolltalk 2002 is composed of a new platform using the same tag sensors, accelerometers, and serial interface. This 2002 version features an animated Alien displayed on a disguised laptop (as opposed to a desktop) computer screen and new modular hand puppets and a puppet

theater which are commercially available (Manhattan toys, 02) though slightly modified for the Dolltalk system.



Hand puppets instead of the original modular dolls were chosen because the children tended to manipulate the dolls using motions which were clearly puppet-like. The design of hand puppets naturally facilitates the imitation of speech motions. Also, it was evident from the 2001 pilot study that the play patterns of the children using the dolls were too complex for the system to analyze. With hand puppets, it is easy to detect when the doll is “talking”—the child simply moves the mouth where the accelerometers are located—and when it is “walking”—the child moves the entire body of the puppet. The two tag readers are now hidden inside two green sculptures which represent the Alien’s hands. The two small speakers are located under the stage and the user wears a wireless microphone. Recording begins when a child removes the two puppets from the green hands. Playback is initiated when both puppets are placed back on the hands. When a child moves a puppet, its mouth blinks and a soft tinkling sound is heard. A tilt-switch sensor located in the mouth is used to activate the sound as well as flash an LED. The voice of the Alien is not computer-synthesized anymore; it is now the recorded voice of an adult pitch-shifted higher in order to imitate the “cute” voice of a child.

Software and framing rules

New analysis code has been written to interpret data coming from the accelerometers. This improved software helps the system to provide more coherent framing clauses and accurate character voice playback. The pilot study showed that children either stop moving the puppets completely or move them in a different way when speaking in a narrator voice. The following rules are used to determine whether or not appropriate framing clauses should be added.

Rule 1: A framing clause is added in between the dialogue of two different characters

Scenario

CHILD: *(Moving the first puppet)* I'm the king! *(Moving the second puppet)* I'm the princess!

The child puts the two puppets on the Alien's hands.

ALIEN: Once upon a time Earthlings were talking. One of them said: *(high voice)* "I'm the king!" *(adding a framing clause)* then the other one replied, *(low voice)* "I'm the princess"

The Algorithm

If the motion of puppet 1 is detected and followed by the motion of puppet 2 without any intervening speech, **then** a framing clause is added in between the two puppets' "speeches."

If the motion of puppet 2 is detected and followed by the motion of puppet 1 without any intervening speech, **then** a framing clause is added in between the two puppets' "speeches."

Interpretation

The first rule defines the case where the child has indicated dialogue for two different characters **without** using a **narrator voice** in between. The narrator's voice then adds a framing clause to clarify to the listener which character is talking.

Rule 2: No framing clause is added in between two characters' dialogue

Scenario

CHILD: *(Moving the first puppet)* I'm the king! *(Without moving the puppets)* Then the girl said: *(Moving the second puppet)* I'm the princess!

The child puts the two puppets on the Alien's hands.

ALIEN: Once upon a time Earthlings were talking. One of them said, *(high voice)* "I'm the king!" *(Playing back the voice of the child)* Then a girl said, *(low voice)* "I'm the princess!"

The Algorithm

If the motion of puppet 1 is detected and followed by speech but no motion then followed by the motion of puppet 2 **then** no framing clause is added in between the two speeches.

If the motion of puppet 2 is detected and followed by speech but no motion then followed by the motion of puppet 1 **then** no framing clause is added in between the two speeches.

Interpretation

This second rule indicates that the child has **already used the narrator voice** between the two different characters' speeches, therefore the system does not need to add a framing clause.

Rule 3: No framing clause is added between two segments of speech from the same character

Scenario

CHILD: (*Moving the first puppet*) I'm the king! (*continuing to move the first puppet*) "I have a beautiful kingdom!"

The child puts the two puppets on the Alien's hands.

ALIEN: Once upon a time Earthlings were talking. One of them said: (*high voice*) "I'm the king! I have a beautiful kingdom!"

The Algorithm

If the motion of puppet 1 is detected and followed by the motion of puppet 1 again **then** no framing clause is added between the two segments of speech.

If the motion of puppet 2 is detected and followed by the motion of puppet 2 again **then** no framing clause is added between the two segments of speech.

Interpretation

The system has stored different segments of speech. This rule is then required to specify under which circumstance a framing clause is not necessary; in other words, whether the child has created multiple lines of dialogue for the same character.

Rules not fulfilled

The rules described above cannot always be fulfilled. For example, children can move the two puppets at the same time while they are talking. Currently, the system creates an average of the motions and attributes the speech to the puppet that has moved the most.

Pilot study

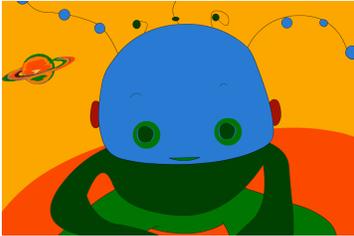
A pilot study with Dolltalk 2002 was conducted with ten children between five and eight years old. The children really liked the "cute"

voice of the Alien and enjoyed listening to its stories. They exchanged stories easily by taking turns with the Alien and they liked hearing their stories played back. For this pilot, two different Aliens were tested for possible use in the final empirical study. The voices for the two Aliens were altered forms of two different adult voices. Children typically found the voice of the first Alien Tuni “cool!” and the voice of the second Alien Zia “really cute.” All six children asked preferred the “cool voice” of Tuni. The children used the puppet theater as a way to indicate story location. They also were clearly more comfortable with the hand puppets than the dolls from the previous study and they had more freedom to act out their stories.

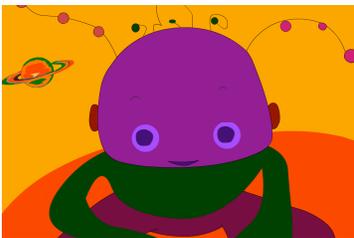


The children frequently used parts of the Alien’s stories and incorporated them into their own. This however presented some limitations; the Alien’s dialogue had to be changed so that no argument could be made that the children were simply parroting back the language they heard. It was also important that the independent and dependent variables for the empirical study were different (*see the user study p.66*). What the Alien needed to do was simply guide the child by suggesting a story topic. The following are design and dialogue elements incorporated into the Alien’s appearance and speech.

Final design



The Alien Tuni



The Alien Zia

Two new drawings of the Aliens, Tuni and Zia, have been created for the final study. As in the previous system, the child takes the two puppets from Zia's hands and they take turns telling stories and listening to the story playback. The significant difference in this version of the interaction occurs at the end of each playback, when Zia talks about the activities and social traditions which take place on its home planet, as a way to prompt the child to play and speak. The following is the additional dialogue spoken by Zia at the end of each playback:

Popular game

That's a good story! You know what, the most popular game on planet Blooper is to race with yellow stars. Kids love to catch and ride on yellow stars. I'm anxious to hear a story about the most popular game on Earth. Can you tell me a story about your favorite game with the two puppets?

Favorite food

Cool! You know kids on planet Blooper love to eat sugar clouds. Kids love to try different flavors of sugar clouds. I'm curious to hear a story about what kids on Earth love to eat. Can you tell me a story about your favorite food with the two puppets?

Birthday parties

Wow! What a great story! Now I know what humans do on Earth! You know kids on planet Blooper celebrate their birthday twice a year. They have big parties twice a year, every year! I'm curious to hear a story about what kids do for their birthday. Can you tell me a story about birthday parties with the two puppets?

Favorite activity at school

I'm so glad you showed me that! You know kids on planet Blooper love to bring their pet Dinosaurs to school and tell a story in front of the class. I'm curious to hear a story about what kids on Earth do at school. Can you tell me a story about your favorite activity at school with the two puppets?

Summary of the components in Dolltalk

Summary of the design and pilot studies of Dolltalk

The first version of Dolltalk in 2000 features a stage platform with stuffed animals. The system plays back the stories in two voices. The children's response to this version was positive; they were laughing and clearly enjoying themselves while repeating the playback often. The

stories were usually unframed; rather they resembled story segments. Children asked where the voices were coming from because they did not recognize both their stories and their voices, and thought that somebody was in the room listening to them. These observations led to the next version.

In the 2001 version, the stuffed animals have become two modular dolls and the stage has become an Alien's platform where the child goes back and forth between telling stories and listening to them played back in the Alien's voice. The playback is made in two different voices and a narrator's voice is added to frame the child's story. Children really seemed to enjoy the modularity of the dolls and to carefully represent the characters that appeared in their storytelling by changing the dolls' props accordingly. The stories told have a beginning and an end and clearly describe to the Alien how children live on Earth. The children also wanted to know more about the Alien's activities. Because the system didn't really differentiate between the types of motions made with the dolls, the system was not always able to distinguish between the character roles in order to pitch shift the sentences correctly. As a result, the children found that the story playback sounded "weird" sometimes. Some of them said, "The Alien doesn't really understand what I say!"

The final version of Dolltalk (2002) features a platform that has become a puppet theater. The dolls have been replaced by modular hand puppets to facilitate the detection of the children's motions. A new set of rules has been implemented for a better interpretation of the children's motions. The Alien now frames the playback of the children's story with a narrator's voice; it also talks about some of the activities on its home planet to prompt the interactions. The puppets make a "cute" sound and blink when the children make them talk. This time the children told the experimenter that they enjoyed the playback of their stories, loved listening to the Alien's activities, and didn't want to stop telling their stories!

Hardware components in Dolltalk

Components	2000	2001	2002
2 RFID tag	Yes	Yes	Yes
2 accelerometers	Yes	Yes	Yes
Serial interface with iRIX board and PIC microcontroller	Yes	Yes	Yes
G4 Macintosh computer	Desktop	Desktop	Laptop
Two speakers	Yes	Yes	Yes
Microphone	Wired	Wired	Wireless
Display of a 2D character on a computer screen	No	Yes	Yes
2 tilt switches	No	No	Yes
2 LEDs	No	No	Yes

Software components in Dolltalk

2000	2001	2002
Real-time analysis software: - Sound analysis - Sensor data analysis - Sentence indexing for 2 character voices	Real-time analysis software: - Sound analysis with environmental noise detection - Sensor data analysis with a filter to detect data more accurately - Sentence indexing for 3 voices: 2 character voices and 1 narrator	Real-time analysis software: - improved background noise detection - Sensor data analysis with a filter to detect data more accurately - Sentence indexing for 3 voices: 2 character voices and 1 narrator
Storing data and sound	Storing data and sound	Storing data and sound

<p>Automated Playback:</p> <ul style="list-style-type: none"> - Sentence segmentation for 2 voices - Speeding up and down the child's voice to change pitch - Sound panning 	<p>Automated Playback:</p> <ul style="list-style-type: none"> - Sentence segmentation for <u>3</u> voices - Advanced algorithm for pitch-shifting child's voice - Animation of 2D character based on sensor data and sound detection - Sound panning 	<p>Automated Playback:</p> <ul style="list-style-type: none"> - Sentence segmentation for 3 voices - Pitch shifting of the child's voice - Animation with respect to sensor data and sound detection - Sound panning - Character framing clause played back using specific rules
<p>Computer-generated voice using Speech Manager commands</p>	<p>Computer-generated voice using Speech Manager commands</p>	<p>Pre-recorded voice</p>



End of Dolltalk Design

How children play with Dolltalk: a user study

Overview of the investigation

Perspective taking is the ability to understand the way characters think and feel, and what motivates them to act.

M. Benson

Narrative perspectives in Dolltalk

Quoted speech

Research has shown that children use play activities to show their narrative knowledge at the time they enter school. At four years of age, children are not only able to make the distinction between narrator and character voices, but they also change their own voices to represent both roles while engaging in play activities (Gardner, 80). Eight-year-old children use verbs of saying such as “say” and “reply” while reporting a dialogue between characters in a story. This clearly helps the listener to identify which character is talking. Children around five to seven years of age tend not to frame their dialogue, making it unclear to the listener which character is talking.

Dolltalk plays back children’s stories in three voices: the narrator voice, and two character voices. Dolltalk aims to encourage children to specify which character is talking. A five-year-old girl would report a dialogue by saying, “I’m grandma” (with the first puppet) and then “I’m grandpa” (with the second puppet). Dolltalk repeats the child’s story by replaying this dialogue and adding necessary framing clauses. For example: “Once upon a time, two Earthlings were talking. One of them said, “I’m grandma.” Then the other one replied, “I’m grandpa.” To respect the coherence of the child’s story, the system detects which character the child is quoting, and assigns one voice-type per character. In other words, from the child’s viewpoint, Zia clearly understands the story by differentiating the dialogue of these two distinct characters—Zia “understands” the turn-taking of the two characters, and their perspectives in the story. The system does not attempt to recreate the child’s story using indirect speech, e.g., “She said that she’s grandma.” This is much more difficult to realize, and involves sophisticated speech and language recognition, but does not accomplish more for the child (Hickmann, 93)

Internal states

Research has shown that children improve their ability to express characters' belief states with adult feedback (Slaughter and Copnik, 96). With Dolltalk the children notice the changes made by Zia to their own stories, and as a result are more detailed in specifying the internal states of story characters in subsequent retellings. By creating special voices for the characters and framing their dialogue, Zia presents the children's stories in a way which more clearly shows the different character perspectives.

Situated learning

Children need to know the reasons for telling a story at any given time. Zia asks children to tell stories about Earthlings; this query situates the task because the child needs to show how Earthlings interact. During pilot studies, the children wanted to exchange stories about life on Earth versus life on Zia's planet. Currently Zia recounts short events about life on Blooper (a fictitious planet near Mars) using specific narrative-perspective methods. This situates the kind of stories that the Alien is impatient to hear by proposing different "story starters," e.g., birthdays, games, activities.

Play patterns in Dolltalk

Knowledge of the self is the mother of all knowledge. So it is incumbent on me to know my self, to know it completely, to know its minutiae, its characteristics, its subtleties, and its very atoms.

Kahlil Gibran

Authorship

Children go through the process of creating their characters in Dolltalk by dressing up the puppets, thinking about the characters in their stories, acting out and telling stories using the puppets, and then listening to their stories retold by Zia. The children aim to be active storytellers by using the puppets as incarnations of their characters and bringing them to life on the stage with their stories. Even after twenty-five minutes of play and storytelling with Dolltalk, they still wanted to continue. They told the experimenter, "I'm not done with my story! I need to tell one more!"

Reflection and revision

Children are encouraged to reflect on their own stories by hearing them played back by the Alien in Dolltalk. Children are given the possibility to revise their stories and to modify them in subsequent attempts (*see discussion p.83*).

Hypothesis

The Dolltalk system acts as an imaginary playmate that takes a different perspective on a child's story. Dolltalk can encourage the expression of narrative perspectives through an open-ended exploration. Based on previous research this narrative feature is important for later literacy skills. This user study tests the following hypothesis:

Children will be more likely to use mental-state expressions to define their characters' belief states after hearing a story dialogue clearly told in different voices.

Methodology

In order to investigate this claim, sixteen children between the ages of six and eight participated in a between-subject study. The study took place in Cambridge, Massachusetts at the school attended by the children. Each child was individually tested and videotaped. Children of this age range were chosen because they are “*actively working on the narratively-complex task of transitioning from oral storytelling to written literacy.*” (Cassell and Ryokai, 01)

This study compares Dolltalk to a regular tape recorder. To reduce the possibility of misleading extraneous factors, both are used in the same setting with Zia speaking identical dialogue. The tape recorder experiment includes all the other aspects used in Dolltalk (e.g., the Aliens' dialogue, the two modular puppets) with the exception of the modified playback. The effect of the Dolltalk system on how children attribute mental states to their characters, how they frame characters' speech in order to specify who is talking, and finally how they use some expressions more generally accepted as predictors of later literacy skills will be discussed.

An attempt was made to be as careful as possible in the selection of the *control* group parameters and to be as specific as possible about which features were being tested. Using a *control* condition that differs significantly in function, for example, comparing a regular toy castle to an electronic toy castle which features an interactive 3D computer-generated character (Ryokai, Vaucelle, and Cassell, 02), makes it difficult to understand the mechanism behind the results. This user study ensures that most of the interface features in both groups are identical. It might be more difficult to find significant results this way, but at least an observer can clearly determine which features in the system can be correlated to the results. Toward this end, a test structure consisting of three stages was created.

The children are randomly assigned to one of two groups. Each group, labeled *Group 1* and *Group 2*, engages the children in three stages of interaction: *Passive Pre-test*, *Active Test*, and *Passive Post-test*. The Active Test interactions are different for the two groups:

- *Active Test for Group 1*: full version of Dolltalk with modified playback of stories.
- *Active Test for Group 2*: playback of stories is unmodified—i.e., “tape recorder” version. This is the *control*.

Both the Passive Pre-test and Passive Post-test are identical for the two groups:

- *Passive Pre-test and Post-test for Groups 1 & 2*: no playback of the stories.

The following table summarizes the experimental conditions:

Group name	Conditions	Length of the interaction	Number of children
Group 1	Passive Pre-test with Tuni	5 min	8
	Active Test with Zia using full Dolltalk system	15 min	
	Passive Post-test with Tuni	5 min	
Group 2	Passive Pre-test with Tuni	5 min	8
	Active Test with Zia using tape-recorder system	15 min	
	Passive Post-test with Tuni	5 min	

At the beginning of all the stages, the experimenter introduces the Alien then leaves the room. In the Passive Pre-Test, the experimenter also presents a sample story to the child. Thus in all conditions children hear an equal number of practice stories before the actual interaction begins. All of the stories told by the children from each stage have been transcribed and analyzed.

Final User Study

Introduction of the two Aliens

For the purposes of the study, two different Aliens have been created: one for the Passive Pre-test and Post-test and another one for the Active Test. The Aliens differ in their physical representation (color), name (Tuni and Zia) and voice (two different adult voices pitch-shifted higher).

The Passive Pre-test and Passive Post-test are used to compare the level of language use before and after the Active Test. The Active Test is used to determine the relationship between each feature of Dolltalk and the child's ability to express narrative perspectives.

Script of the Passive Pre-test with the Alien Tuni

The experimenter puts a wireless microphone (called a "little backpack" in the script) on the child at the beginning so that the microphone does not disturb the child during the interaction.

EXPERIMENTER: Let me put this little backpack on you. I want to introduce you to two Aliens: Tuni and Zia. They want to talk to you. Tuni gets here first, but Zia will talk to you right after. Let's talk to Tuni!

TUNI: Hello! My name is Tuni. I'm seven years old. I'm here with my friend Zia and we are really curious about people on your planet. Zia is still in the spaceship, but Zia will come soon. Will you play with these two puppets and show me how kids live on planet Earth?

EXPERIMENTER: You see the puppets here? You can dress them up any way you want and tell a story to Tuni using the puppets. Now, let's dress them up! Then, we will tell our stories! When we are done with our story, we will put the two dolls onto Tuni's hands.

TUNI: Ready? Let's go!

EXPERIMENTER: *(Using the two puppets)* Once upon a time, there were two friends playing outside in a beautiful park. One of them, Tom, wanted ice cream. Then he said to Mary, his friend: "I would like some ice cream. Can I get some for you too?" Then, Mary said, "Oh yes, I love ice cream. Please get me some vanilla!" Then, the two friends were having fun eating their ice cream. The end. *(Putting the two puppets on Tuni's hands)* Now let's give the two puppets back to Tuni and see what happens! *(Giving one puppet to the child)* You want to give Tuni the second one?

The child gives the puppet back.

TUNI: That's a good story! Let's do it again! When you are done, just put the two puppets on my hands! Let's go!

EXPERIMENTER: Because Tuni prefers to stay with you, I will come back in five minutes. I will be right outside. Now, it's your turn to tell a story, you just need to put the two puppets on Tuni's hand to give Tuni a turn!

During the Passive Pre-test, the child plays for five minutes with Tuni. The child tells stories, and gives the two puppets back to the Alien. The child receives a different prompt (similar to, "That's a good story. Let's do it again!") each time he or she returns the two puppets. After five minutes, the experimenter comes back. After the child is done with the current story, Tuni starts speaking again.

TUNI: I gotta go, but I will be back!

Script of the Active Test with the Alien Zia

The experimenter introduces the second Alien, Zia.

EXPERIMENTER: Tuni has to go to let Zia talk to you. Now, let's connect us to Zia!

ZIA: Hey! I'm Zia, Tuni's best friend! I also want to hear your story! You can play with these two puppets, and maybe you can show me how kids live on Earth.

EXPERIMENTER: You can play with the same puppets and tell a story with them! You tell a story first and you put the puppets back on Zia's hands, and then Zia tells a story back. (*Showing the two puppets to the child*) Because Zia prefers to stay with you, I will be back in fifteen minutes. You can play as long as you want with Zia, and I will be right outside. Now, it's your turn. You just need to put the two puppets on Zia's hands to give Zia a turn! Are you ready?

ZIA: Ready? Let's go!

The experimenter leaves the room. The child tells a story then puts the two puppets on Zia's hands.

ZIA: That's so cool, let me see if I understand, do you mean this?

Group 1 only:

ZIA: *(Introducing the story of the child)* Once upon a time Earthlings were talking.

Zia plays back the story of the child using four different voices: A low-pitched voice for one puppet, a high-pitched voice for the second puppet, the regular voice of the child for the narrator, and its own voice for added framing clauses.

Group 2 only: *Zia plays back the story of the child like a regular tape recorder.*

Both Groups:

The child takes the two puppets from the hands of Zia and takes turn telling stories and listening to the stories played back. At the end of the play back, Zia prompts the play by mentioning social traditions that are done on planet Blooper. After fifteen minutes, the experimenter comes back and Zia starts speaking.

ZIA: I gotta go now, because it's Tuni's turn to talk to you. I'll see you later!

Script of the Passive Post-test with the Alien Tuni

EXPERIMENTER: Tuni has been waiting for a long time to talk to you one more time. Let's connect you to Tuni!

TUNI: *(Appearing on the screen)* Hi! I'm back! Was it fun? Do you remember me? I'm Tuni.!!! I want to know what you told Zia about people on planet Earth! Will you use these dolls to show me what you told Zia?

EXPERIMENTER: Because Tuni prefers to stay with you, I'll come back in five minutes. I will be right outside. Now, it's your turn to tell a story! You just need to put the two puppets on Tuni's hand to give Tuni a turn!

TUNI: Ready? Let's go!

The experimenter leaves the room. The child tells a story then puts the two puppets on the hands of Tuni.

TUNI: That's a good story! Let's do it again! When you are done, just put the two puppets on my hands! Let's go!

After five minutes, the experimenter comes back and after the child is done with the current story, Tuni begins to move.

TUNI: Oh no! Our spaceship is leaving! I gotta go, bye!

Findings

Dolltalk gives children a chance to express and explore narrative perspectives. The children's narratives are analyzed with respect to the narrative perspective skills described on p.26.

Data analysis

Internal states

Playing with the Dolltalk system improves a child's ability to attribute internal states to characters in storytelling (*see definition of internal states on p. 29*).

The following transcript is a story, told by an eight-year-old boy playing with Dolltalk, that uses mental-state expressions.

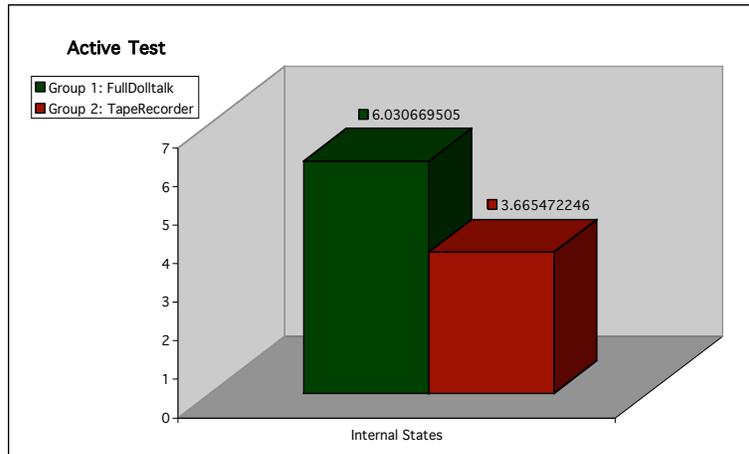
Example of a story with internal-state expressions

Parents, ah, um, kids on the planet Earth love to eat ice-cream. When they eat it, they always say, "Ah, what a good flavor. I love ice cream. I wish we could get it again. Can I, dad?" And the dads always say, "Yes." And so they keep coming and coming. And Bee-Bee, do you want to come? Well, yeah. Well, why are you so mad? Because I want ice cream. OK, then, ah, ah, let's eat ice cream. So Bee-Bee and Bah-Bah went to buy ice cream at an ice cream shop with vanilla, strawberry and, and, ah, chocolate flavor. And so Bee-Bee and Bah-Bah ate everything in the shop. They loved it so much that they ate everything. They had a bellyache in the end. And when they fini-, and when they went home they laid down and went to bed and sleep for a whole week. The end.

All of the transcribed stories were analyzed for frequency of internal-state expressions. Given the duration of each story, the number of expressions per minute was calculated.

Results

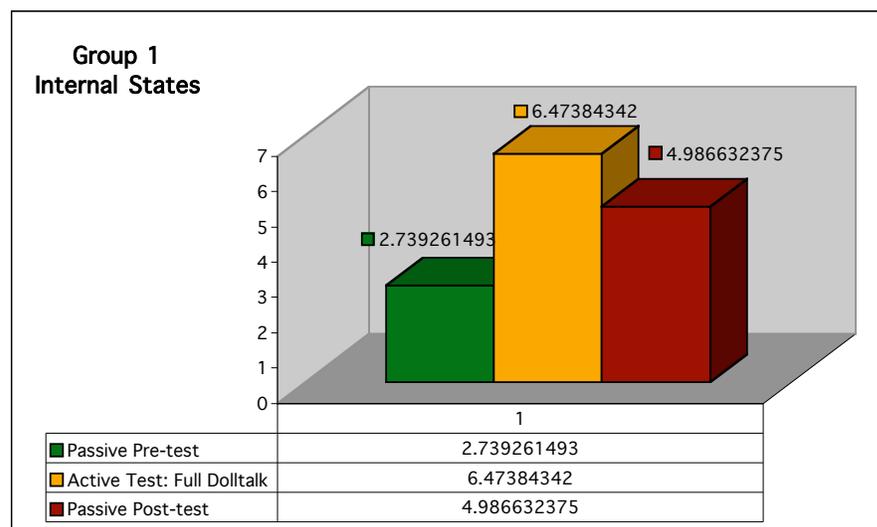
The following chart represents the sum of internal-state expressions used by the sixteen children during the Active Test.



This chart shows that the eight children in Group 1 have a mean of 6.0305 internal-state expressions per minute and that the eight children in Group 2 have a mean of 3.6651 internal-state expressions per minute. This seems to indicate that using Dolltalk encourages children to express character perspectives. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value of .04, indicating that the means of the two groups **differ significantly** ($p < .05$).

In order to compare the stories told in the Passive Pre-test (a five-minute session) to the Active Test (a fifteen-minute session), only the first couple of stories were used, allowing for an equal time slice analyzed for each stage.

Group 1: Active Test with Full Dolltalk System



Passive Pre-test and Passive Post-test

This chart shows that children in the Passive Pre-test have a mean of 2.7391 internal-state expressions per minute and that children in the Passive Post-test have a mean of 4.9864 internal-state expressions per minute. This seems to indicate that children retain what they learned from their interaction with the Active Test (Full Dolltalk) and apply it in the Passive Post-test. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value of .041, indicating that the means of the two groups **differ significantly** ($p < .05$).

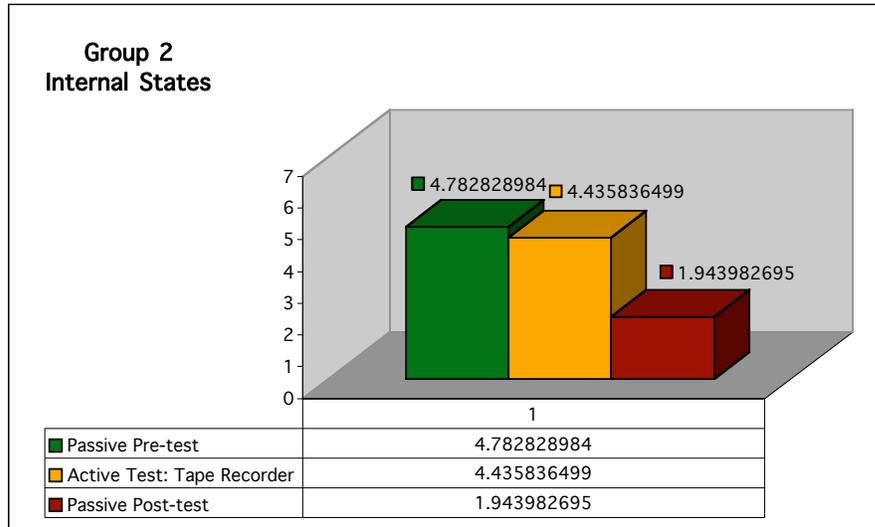
Passive Pre-test and Active Test (Full Dolltalk)

This chart shows that children in the Passive Pre-test have a mean of 2.7391 internal-state expressions per minute and that children in the Active Test (Full Dolltalk) have a mean of 6.4738 internal-state expressions per minute. This seems to indicate that using Dolltalk encourages children to express character perspectives. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value of .013, indicating that the means of the two groups **differ significantly** ($p < .05$).

Active Test (Full Dolltalk) and Passive Post-test

This chart shows that children in the Active Test have a mean of 6.4738 internal-state expressions per minute and that children in the Passive Post-test have a mean of 4.9864 internal-state expressions per minute. This seems to indicate that children express character perspectives less frequently without the use of the Dolltalk system. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Group 2: Active Test with Tape Recorder



Passive Pre-test and Passive Post-test

This chart shows that children in the Passive Pre-test have a mean of 4.7828 internal-state expressions per minute and that children in the Passive Post-test have a mean of 1.9439 internal-state expressions per minute. This seems to indicate that children have not improved their ability to express the internal states of story characters during the Passive Pre-Test stage and the Active tape-recorder stage. The use of mental-state expressions has even decreased, and the tape-recorder playback seems to discourage children from expressing character perspectives. Levene’s Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a *p*-value of .032, indicating that the means of the two groups **differ significantly** ($p < .05$).

Passive Pre-test and Active Test (Tape Recorder)

This chart shows that children in the Passive Pre-test have a mean of 4.7828 internal-state expressions per minute and that children in the Active Test (Tape Recorder) have a mean of 4.4355 internal-state expressions per minute. This seems to indicate that using the tape-recorder version does not encourage children to express character perspectives. Levene’s Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a *p*-value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Active Test (Tape Recorder) and Passive Post-test

This chart shows that children in the Active Test have a mean of 4.4355 internal-state expressions per minute and that children in the Passive Post-test have a mean of 1.9438 internal-state expressions per

minute. This seems to indicate that children express character perspectives less frequently without the use of the tape-recorder system. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $>.05$, indicating that the means of the two groups **do not differ significantly**.

Quoted speech

The following transcript is a story, told by another eight-year-old boy playing with Dolltalk, that uses framing clauses to introduce the characters.

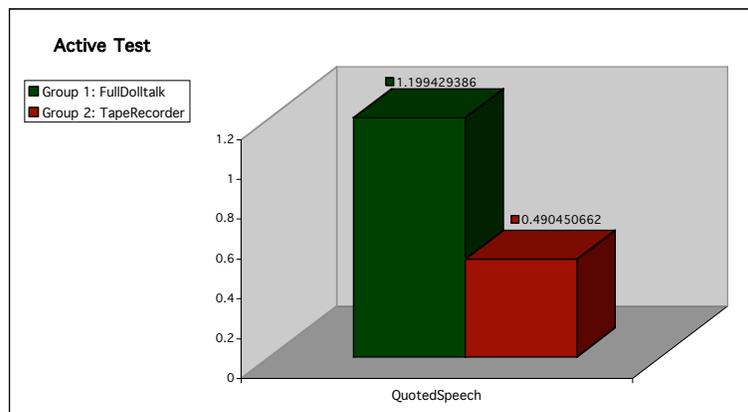
Example of a story with quoted speech and framing clause

Once upon a time there were, there was a girl in the forest. She was looking for someone to play with but she couldn't find someone. She yelled, "Is anyone here?" And then a boy came up and said, "Yes, I'm here. What's your name?" "My name is Christina. What is yours?" "My name is Tommy." So he, Tommy said, "What is your favorite color?" "Mine is pink. What is yours?" "Mine is white. Do you want to play tag?" "Yes I would." "So, not it. I am." "OK, I'm it," said Chri-, um, Christina. And then she went, "Tag, you're it. Tag, you're it. Tag, you're it." The end.

All of the transcribed stories were analyzed for frequency of framing clauses. Given the duration of each story, the number of expressions per minute was calculated.

Results

The following chart represents the sum of quoted speech with framing clauses used by the sixteen children during the Active Test.

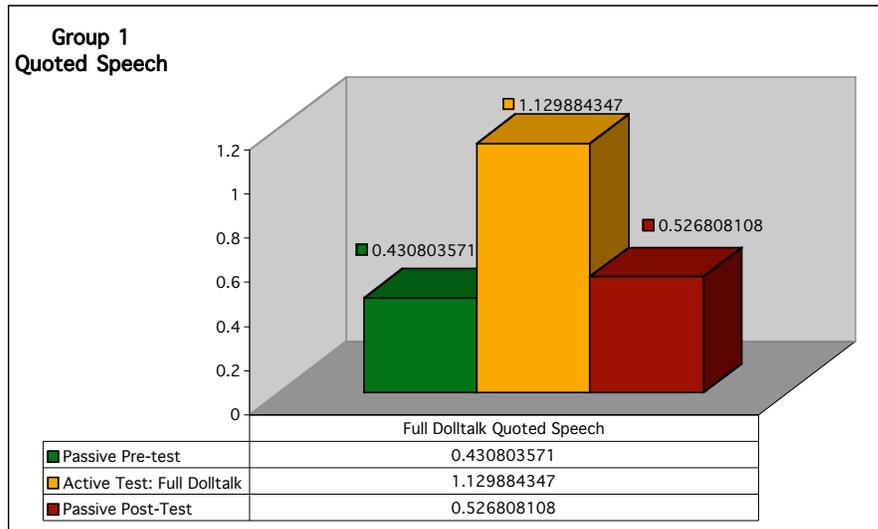


This chart shows that the eight children in Group 1 have a mean of 1.1993 quoted speech with framing clauses expressions per minute and

that the eight children in Group 2 have a mean of 0.4904 quoted speech with framing clauses expressions per minute. This seems to indicate that using Dolltalk encourages children to introduce characters' dialogue. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $>.05$, indicating that the means of the two groups **do not differ significantly**.

In order to compare the stories told in the Passive Pre-test (a five-minute session) to the Active Test (a fifteen-minute session), only the first couple of stories were used, allowing for an equal time slice analyzed for each stage.

Group 1: Active Test with Full Dolltalk



Passive Pre-test and Passive Post-test

This chart shows that children in the Passive Pre-test have a mean of 0.4308 framing clauses per minute and that children in the Passive Post-test have a mean of 0.5268 framing clauses per minute. This seems to indicate that children retained a little of what they learned during the Active Test. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $>.05$, indicating that the means of the two groups **do not differ significantly**.

Passive Pre-test and Active Test (Full Dolltalk)

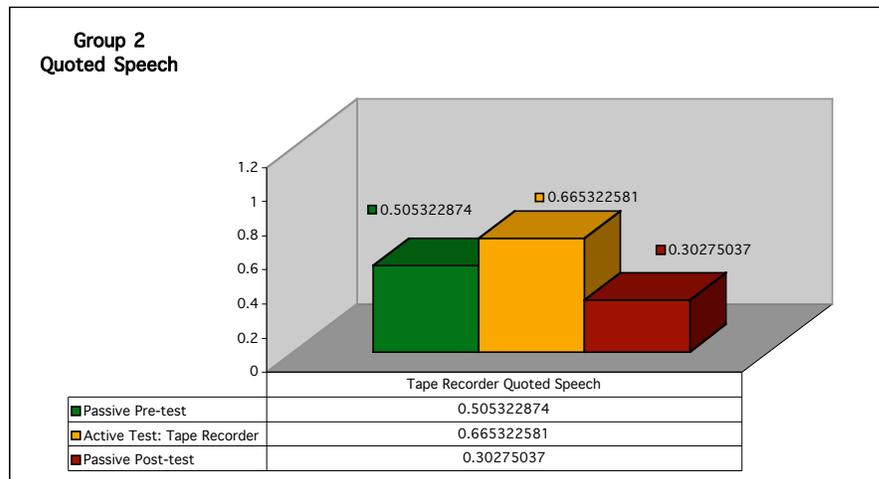
This chart shows that children in the Passive Pre-test have a mean of 0.4308 framing clauses per minute and that children in the Active Test (Full Dolltalk) have a mean of 1.129 framing clauses per minute. This seems to indicate that using Dolltalk encourages children to frame

character dialogue. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Active Test (Full Dolltalk) and Passive Post-test

This chart shows that children in the Active Test have a mean of 1.129 framing clauses per minute and that children in the Passive Post-test have a mean of 0.5268 framing clauses per minute. This seems to indicate that children introduce characters' dialogue less frequently without the use of the Dolltalk system. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Group 2: Active Test with Tape Recorder



Passive Pre-test and Passive Post-test

This chart shows that children in the Passive Pre-test have a mean of 0.5053 framing clauses per minute and that children in the Passive Post-test have a mean of 0.3027 framing clauses per minute. This seems to indicate that children do not retain what they have learned from their interaction with the Active Test (Tape Recorder) in their next storytelling attempt during the Passive Post-test. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Passive Pre-test and Active Test (Tape Recorder)

This chart shows that children in the Passive Pre-test have a mean of 0.5053 framing clauses per minute and that children in the Active Test (Tape Recorder) have a mean of 0.6653 framing clauses per minute. This seems to indicate that using the tape-recorder version encourages children to introduce characters' speech a little. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Active Test (Tape Recorder) and Passive Post-test

This chart shows that children in the Active Test have a mean of 0.6653 framing clauses per minute and that children in the Passive Post-test have a mean of 0.3027 framing clauses per minute. This seems to indicate that children introduce characters' dialogue less frequently without the use of the tape-recorder system. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value of $.04$, indicating that the means of the two groups **differ significantly** ($p < .05$).

Spatial and temporal expressions

Dolltalk's influence on the spatial and temporal expressions used by the children has also been analyzed. Previous research on technological toys (Ryokai and Vaucelle, and Cassell, *in press*) has looked at how a storytelling toy can support children's preliteracy skills. This research defined spatial expressions as information about *where* an event takes place and temporal expression as information about *when* the event takes place (Peterson, Jesso, and McCabe, 99). The use of these expressions is analyzed in this study because the Alien asks for information about the child's life and the child is in the position to provide some contextual information.

The following transcript is a story that uses spatial expressions, told by a six-year-old girl playing with Dolltalk.

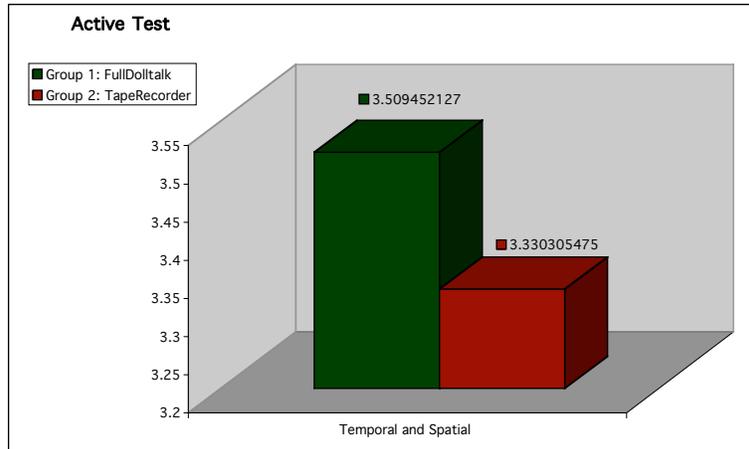
Example of a story with spatial expressions

Once upon a time, there was two friends and they were happy together. So one of them said to the other, "do you want to play?", and the other one said, "OK" and so they went to the park. One of them went on the swings, the other one went on the slide. The one, the person that was on the swing, they got hurt. Then the other one went to the swing and picked her up to, to see if she's alright, and she was. The end.

All the transcribed stories were analyzed for frequency of temporal and spatial expressions. Given the duration of each story, the number of expressions per minute was calculated.

Results

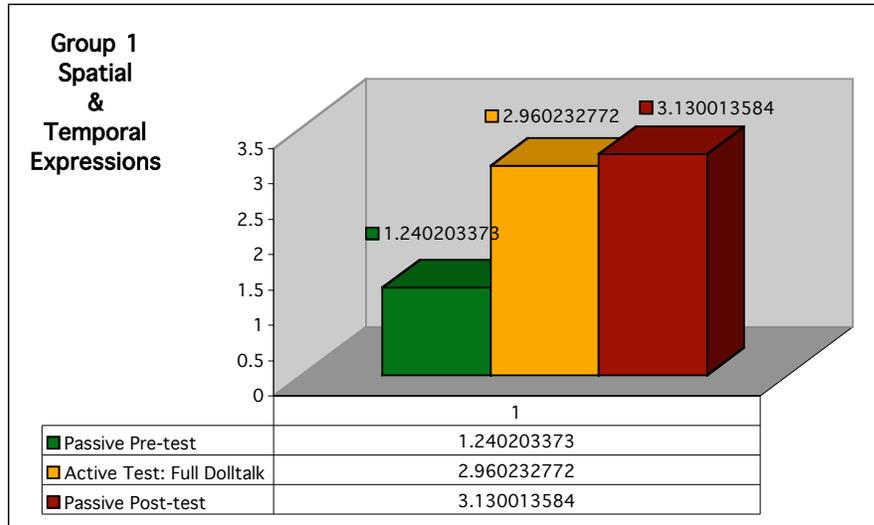
The following chart represents the sum of temporal and spatial expressions used by the sixteen children during the Active Test.



This chart shows that the eight children in Group 1 have a mean of 3.5091 temporal and spatial expressions per minute and that the eight children in Group 2 have a mean of 3.33 temporal and spatial expressions per minute. This seems to indicate that using Dolltalk encourages children to provide some contextual information about where and when the action of the story takes place. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $>.05$, indicating that the means of the two groups **do not differ significantly**.

In order to compare the stories told in the Passive Pre-test (a five-minute session) to the Active Test (a fifteen-minute session), only the first couple of stories were used, allowing for an equal time slice analyzed for each stage.

Group 1: Active Test with Full Dolltalk



Passive Pre-test and Passive Post-test

This chart shows that children in the Passive Pre-test have a mean of 1.2402 spatial and temporal expressions per minute and that children in the Passive Post-test have a mean of 3.13 spatial and temporal expressions per minute. This seems to indicate that children retain what they learned from their interactions with the Dolltalk system during the Active Test, and apply it during the Passive Post-test. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Passive Pre-test and Active Test (Full Dolltalk)

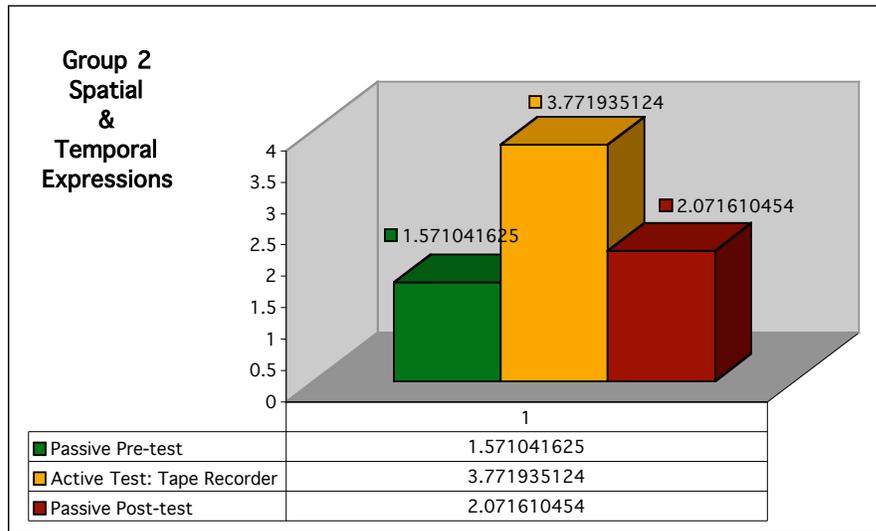
This chart shows that children in the Passive Pre-test have a mean of 1.2402 spatial and temporal expressions per minute and that children in the Active Test (Full Dolltalk) have a mean of 2.9602 spatial and temporal expressions per minute. This seems to indicate that using Dolltalk encourages children to provide spatial and temporal information in their stories. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Active Test (Full Dolltalk) and Passive Post-test

This chart shows that children in the Active Test have a mean of 2.9602 spatial and temporal expressions per minute and that children in the Passive Post-test have a mean of 3.13 spatial and temporal

expressions per minute. This seems to indicate that children provide more spatial and temporal information in their stories without the use of the Dolltalk system. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Group 2: Active Test with Tape Recorder



Passive Pre-test and Passive Post-test

This chart shows that children in the Passive Pre-test have a mean of 1.571 spatial and temporal expressions per minute and that children in the Passive Post-test have a mean of 2.071 spatial and temporal expressions per minute. This seems to indicate that children retain some of what they learned from their interaction with the tape-recorder version of the Active Test, and apply it during the Passive Post-test. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

Passive Pre-test and Active Test (Tape Recorder)

This chart shows that children in the Passive Pre-test have a mean of 1.571 spatial and temporal expressions per minute and that children in the Active Test (Tape Recorder) have a mean of 3.771 spatial and temporal expressions per minute. This seems to indicate that using the tape-recorder encourages children to provide spatial and temporal information in their stories. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could

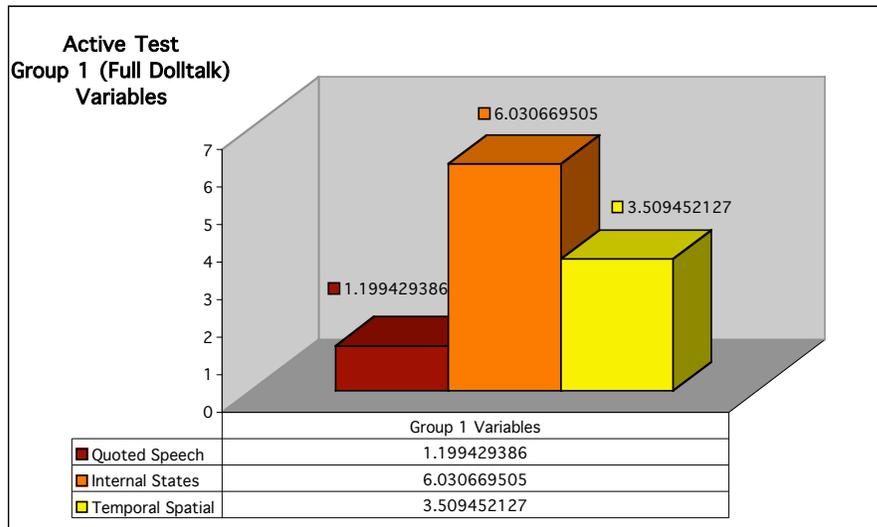
have happened by chance. The test results in a p -value $> .05$, indicating that the means of the two groups **do not differ significantly**.

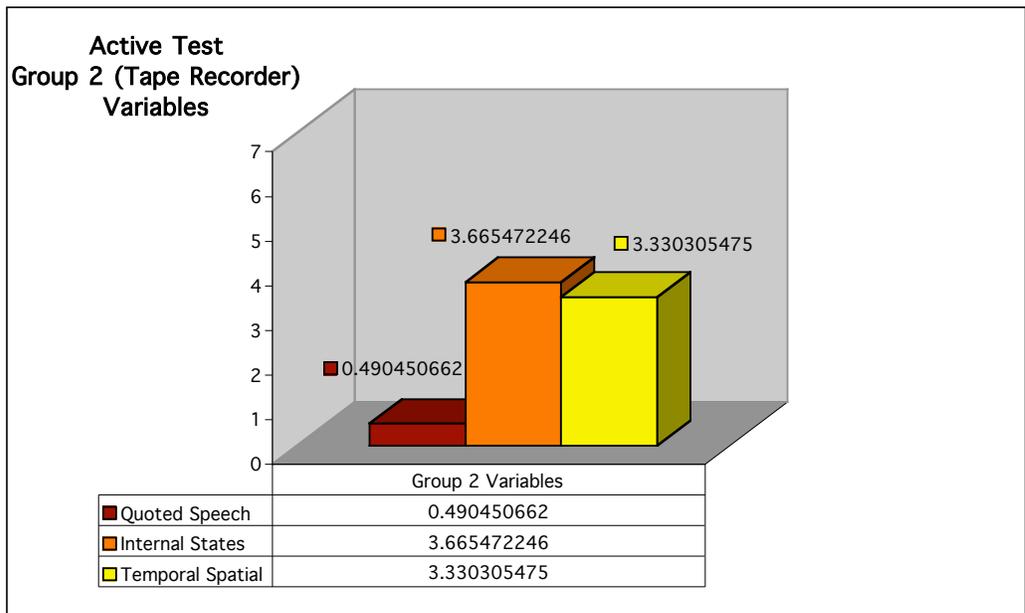
Active Test (Tape Recorder) and Passive Post-test

This chart shows that children in the Active Test have a mean of 3.771 spatial and temporal expressions per minute and that children in the Passive Post-test have a mean of 2.071 spatial and temporal expressions per minute. This seems to indicate that children provide more spatial and temporal information in their stories with the use of the tape-recorder system. Levene's Test for Equality of Variances is used to determine the probability of whether or not the results could have happened by chance. The test results in a p -value of .035, indicating that the means of the two groups **differ significantly** ($p < .05$).

Summary

The following chart represents the sum of the variables: internal states, quoted speech with framing clauses, and temporal and spatial expressions.





Both the full Dolltalk system and the tape recorder system encourage children to express the internal states of their characters, provide spatial and temporal information, and frame characters' dialogue. However, the difference between the frequency of internal-state expressions and the frequency of temporal and spatial expressions is small for the tape recorder (3.66 for I.S. and 3.33 for S.T.), while the difference is quite large for the full Dolltalk system (6.03 for I.S. and 3.50 for S.T.). The main feature of Dolltalk seems to be its ability to encourage children to express the internal states of their characters.

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End of User Study

Conclusions

Discussion about the User Study

The most significant results indicate that the voicing and framing clauses added by Dolltalk encourages children to attribute internal states to their story characters much more than unmodified playback. Children also express internal states of characters far more with the Active Dolltalk system than the Passive system, as shown in the results comparing the Passive Pre-test to the Active Test for Group 1. Furthermore comparison between the results for the Passive Pre-test and Passive Post-test in Group 1 indicates that children retain what they learned from the Dolltalk system (during the Active Test) and apply it in the Passive Post-test.

Another significant result has been found between the Passive Pre-test and Passive Post-test for Group 2. The use of internal-state descriptions *decreases* after the use of the tape recorder, indicating that unmodified playback does not help or even discourages the child from incorporating internal-state expressions in their storytelling.

Children appeared to use framing clauses far more often when using the Dolltalk system versus the tape recorder, however no *significant* results have been found indicating this.

No statistical differences have been found between the Passive and Active test in the use of temporal and spatial expressions. It is interesting to note that regardless of the playback features of Dolltalk, the presence of the Alien in all cases invites the use of temporal and spatial expressions by the children. This seems to confirm what has been noticed in the Sam study (Ryokai, Vaucelle and Cassell, 02); the presence of an animated character appears to encourage children to use more spatial and temporal expressions in their stories. Children adapt their stories according to the Alien's by providing information about where they live and what happens in their lives. The following is an excerpt from a story told by an eight-year-old girl:

On the planet Earth, kids love to sing songs. Where we're telling you the story, we're kind of close to the Music Room in our school. They're singing "My Country 'Tis of Thee" in there.

Children also tell stories by borrowing elements from real life ("the playground") and transforming them into their fantasy world ("the scene of the crime"). The following is an excerpt from a story told by another seven-year-old who uses spatial expressions during the Passive Pre-test; in this story, the "playground" becomes the "scene of the crime":

Once upon a time, two little monsters were walking down the street one day. They were headed toward the playground. One said, "Do you want to play?" The other said, "Yes." They went to the playground, but when they got there they saw that the playground was empty. One said, "That's funny. That's funny, last week when I went here there were lots of people playing here and now there's none. What might have happened to them?" "Hmm," they both thought. Then one got an idea. "Maybe someone kidnapped them." "You're right, like a bully. Let's go to the scene of the crime." And they went to the playground. "Do you see any clues?" "No, but what's this?" "It's a paper, it says you will never see the kids again, only if you write a hundred words and then chop the tallest tree in the woods down."

In their interactions with the Alien, children asked specific information about the Alien's life using spatial descriptions. The following is an excerpt from a story told by a seven-year-old boy:

So, that's why I think it should be important to play with your sisters, because I think it's fun playing with your family. But sometimes, it's nice to leave them alone for a little while. And so, I want you to tell me about your family on your planet. And that's why I want to know what they have done on your planet. My planet is very, very fun. Hmmm. I, what's a, a spa, I'm wondering how do your spaceships traced?

These examples show that a peer listener such as the Alien encourages more detailed stories with temporal expressions (e.g., specific birthday parties) and spatial expressions (e.g., planet Earth).

During the course of the study, children told stories with Dolltalk that described their activities, complex plots, and complex feelings. Children talk about these feelings and experiences by bringing them to life using the two puppets. The following is the transcript of a story told by a six-year-old girl. This child was telling the Alien about a traumatic event that happened in her life.

Once upon a time, there was two friends and they were happy. One of them said, "A long time ago, I hurt myself, so I had to get stitches and I had to go to the hospital." And the other one said, "That's so sad." "I know, I didn't like it. They had to give me bad medicine. Bye." The end.

Dolltalk as a *speech-therapy kindergarten* provides a sense of physical and emotional safety with soft materials and toys. The Alien encourages the expression of feelings. Dolltalk also works as an effective platform for *play therapy*, directed by the Alien in an unobtrusive way, allowing the child to lead.

Future Work

It was surprising how much children enjoyed telling and listening to stories and playing with the Alien. It's too bad that the Alien could not reply to their questions about life on its home planet! There are other features that could be added to Dolltalk which could potentially make it even more engaging for children.

In future work, given the enthusiasm of the children, it might be effective to play back the motions of the puppets to show them "conversing" with each other. This could keep the attention of the child and emphasize the character perspectives in the story. Two servo-motors, connected to the system, could be used to move each puppet while the Alien is retelling the story.

As mentioned by Daniela O'Neill, more work could be done to improve the "naturalness" of the story playback by incorporating names or other such features into the framing clauses to enhance coherence and interpretability. It would be nice if children somehow gave the characters names to begin with, perhaps in a separate introduction before telling the stories. The Alien could ask at the beginning of the interaction, "What's the name of the green puppet?" and could wait for the child's answer, record it, and play it back when necessary.

Dolltalk currently uses two different framing clauses: "one said" and "the other one replied." In a future version, it could be simplified by only using "one said" during the entire interaction since "the other one replied" is not always appropriate. Children could get turned off by the toy very quickly if their stories do not make sense when played back.

While the system has no problem detecting the two puppets moving simultaneously, determining which puppet is the main character is difficult. The current system measures the average number of motions

per puppet per utterance and chooses the one with the larger average if both are moving. Perhaps a better solution would be to use the narrator voice (no pitch-shifting) when this occurs. Improved analysis of sensor data as well as additional types of sensors could also provide a more accurate definition of the play patterns of the children. By combining different types of sensors such as bend sensors (in the neck of the puppet), touch sensors (on the puppets), and accelerometers (inside the head), a machine-learning technique could be used to determine exactly how children are manipulating the puppets. This increased knowledge of play patterns could help the system provide more coherent feedback during the interaction.

Finally, an empirical study on the effect of adding framing clauses and voicing, independent of one another, might provide additional insights on children's capability to express character perspectives. The playback may not need added framing clauses to encourage children to express the mental states of the characters. Deeper empirical research could be conducted to understand the effect of this specific feature on the stories of children. Based on the results of this study, it cannot be argued that Dolltalk actually affects the use of spatial and temporal expressions any more than tape-recorded playback. But this is an interesting result that merits further study. This may help clarify exactly what kind of narrative abilities are enhanced when playing with Dolltalk.

In the meantime, Mattel has been developing a commercial version of Dolltalk. While it has been a real pleasure to work with them, it is important to keep in mind that a commercially-viable toy will probably lack many of Dolltalk's advanced features. Nonetheless a toy that is still interesting and engaging for children and keeps much of the content of the original Dolltalk is still possible.

Although two children can play together with the current Dolltalk system, this aspect could be explored further. A study investigating the usability of Dolltalk for two children could result in additional improvements to the system and lead to new research in the area of computer-supported collaborative learning.

Dolltalk could be used as a platform to take the expression of perspectives one step further. As proposed by Hiroshi Ishii, children could use wearable props to dress themselves as a character. For example putting on a farmer's cap would mean the child would talk for a farmer's perspective. These wearable props could be recognized by the Alienm who would then ask specific questions relevant to the respective character.

This new version of Dolltalk could even work for people of all ages as a way to exchange perspectives and to encourage people to reflect on other's perspectives. This might be particularly relevant teenagers. Older children who have difficulties resolving conflicts could be challenged with such a system to resolve problems in their interactions with other people.

The Alien's speech could be modified for different topics. For example the Alien could ask questions regarding fundamental issues such as love and death. During the course of the user study, children demonstrated that they were very interested in the fundamental questions of life. Props could be added symbolizing these fundamental topics and used in the process of exchanging stories. A child could choose one of these props, for example showing a "love" symbol, and place it in front of the Alien. The Alien would then tell stories about what love means on its home planet, and then ask the child, "I want to know how people love each other on Earth."

Final Word

The Dolltalk system builds upon many related systems in the fields of narrative research and Human Computer Interaction for children. This thesis explains how a child may benefit from an interaction with the Dolltalk story-listening toy. Preliteracy skills, presented in the framework of emergent literacy, have helped illuminate the aspects of storytelling that Dolltalk encourages a child to express.

The various studies outlined in this thesis show that not only does Dolltalk further children's ability to express belief-states of others, but it also promotes more descriptive storytelling. Based on these results, as well as the enjoyment of the children during Dolltalk interactions, it appears that they really consider the Alien an audience and peer.

In short, by using Dolltalk, we can gain insight and awareness into a child's world through their primary means of communication: play.



End of Conclusions

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