Introduction

This chapter describes the theory and practice behind the development of interactive toy interfaces for children. These toys, which resemble familiar characters from children's media, use social mimicry as an interface strategy. Their movement and speech are scripted based on an implicit understanding of the social rules for each interaction, social rules children themselves already obey. These character-based interfaces are designed to build on children's social expectations not just to improve the usability of technology for young users, but also to promote learning and development by applying proven social learning methods to technology interaction. The chapter is organized into three sections. The first section provides an overview of the theory and research behind the development of these physical character interfaces. The second section describes how the theory was applied during the product development process for different character-based interfaces for three specific age groups, and how research with users shaped the interfaces so that they matched the abilities and expectations of the target age groups. Finally, current knowledge and future directions for technology interactions using character-based interfaces is discussed.

Why make technology interactions more like human interactions?

Traditionally, computers and technology have been viewed as powerful, if impersonal, additions to modern life. The assumption has been that technology is simply a tool, similar to a hammer or washing machine, that helps users to either accomplish existing tasks (such as producing spreadsheets or documents) more quickly and easily or helps them to do new things (such as prototype and test virtual examples of new product designs) that would have been impossible using traditional techniques, such as hand drafting. As interactivity has expanded both in scope and in complexity, integrating computational intelligence with media such as voices and images, a promising new strategy for interface design has emerged in recent years that complements the tool model. This new strategy is to treat human-computer interaction not as if it were a functional interaction between a worker and a tool, but rather as if it were a social interaction between two people instead (Frohlich, 1997; Sidner, 1997; Terveen, 1995;Thorisson, 1994). Treating the computer as a partner rather than a tool is thought to be beneficial to users because such collaboration, built on

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models of collaboration between humans, distributes the burden of remembering, ordering, and executing all the elements of a given task between the computer and the user, rather than requiring the user to always be in control of all aspects of the effort (Maes, 1997).

Aside from the advantages of such a collaboration in terms of relieving task-demand burdens from the user, treating the computer as a social partner has another powerful argument in its favor: Users already respond to computers as if they are social agents, endowing them with such properties as personality, politeness, gender, and more (Fogg and Nass, 1997; Morkes, Kernal, and Nass, 1998; Nass, Steuer, and Tauber, 1994). So pervasive is this tendency to endow computers with human attributes that it has given rise to its own interface model, Computers As Social Actors (CASA). The CASA model presumes that such human-like attributions to technology can actually be deliberately induced in users through specific interface features: “The CASA paradigm maintains that individuals can be induced to behave *as if* computers warranted human considerations, even though users *know* that the machines do not actually warrant this treatment…[Fogg and Nass, 1997, p.552, italics in original].” Exploiting the social expectations of users for both collaborative interactions and for other technology interfaces holds great promise as a consumer interface. Social interfaces can make technology interactions simpler and more intuitive because they are built on implicit social understandings that users already have, and hence require no extra learning or accommodation. In conversation, for example, dialogue takes the form of simple turn taking between speakers. Structuring audio interactions between users and computers to capitalize on this already-established expectation about interpersonal speech gives the interface a familiar feel to the user, and can make the interaction go more smoothly as a result. (Sidner, 1997; Thorisson, 1994).

Using the conventions of social interaction as a model for technology interaction has even more value when the target users are very young. Consider the cognitive and motor limitations young children bring to the interface. Presenting information is a significant challenge. The target user has a short attention span, cannot read, and has a shaky understanding of letters, numbers, shapes, and even colors. In terms of input, young children have immature fine motor skills, cannot write, have limited vocabularies and poorly articulated speech. The typical interface design, conceived as a tool, is a manual point device that presents these users with a variety of serious obstacles. But what young children lack in physical and

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cognitive competence they make up for in social expertise. By the end of the first year, infants show differential, social responses to humans as compared to other animate stimuli such as mechanical dolls or other objects. They begin engaging in social strategies such as joint attention (following the gaze of another person to see what they are reacting to, for example) and imitation of novel actions with objects previously witnessed only once (Muir and Nadel, 1998). By the end of the second year, very young children, even those without language, understand the basic rules or 'scripts' for different kinds of social interaction -- and change their own behavior accordingly (Furman and Walden, 1990; Garner, Jones and Palmer, 1994). Mimicking social behavior in the interface builds on children's social competence to support technology interactions for young users not served by existing point-and-click interfaces.

It is possible to exploit social competence and social expectations in the interface for more ambitious goals than ease of use. Rules of human social interaction can be used not just to define the form of technology interactions, but the content of such interactions as well. Human interaction is charged with emotion, and there is significant data on the role of emotions in behavior. Interaction with the interface character will need emotions, as well. One consistent finding in the psychological literature is that positive emotional interactions such as praise, affection, and humor are associated with better learning and a variety of other positive developmental outcomes (Bornstein, 1989; Coleman, 1992; Jennings and Connors 1989; McGhee, 1988). The character's ability to convey emotions provides a unique opportunity to bring these feelings to children as part of toy play. Another consistent finding is that specific kinds of social interactions can promote learning, particularly when the interactions involve other media such as computers or television (Haefner and Wartella, 1987; Nastasi and Clements, 1992; Collins, Sobol, and Westby, 1981; Tudge, Winterhoff, and Hogan, 1996). Despite this evidence that social interactions augment learning with electronic media, the fact is that watching television is typically a solitary experience for children, except in formal educational settings like schools (Huston, Fairchild, Katz, Murray, Rubinstein, Wilcox, and Zuckerman, 1992). The social interactions are considered separate from the computer or television content, in a different realm. Social interfaces, with their explicit reliance on human social interaction as a basis for design, present a unique opportunity to integrate beneficial emotional and social-cognitive interactions into learning and interacting with different media. Social interfaces can broaden the range of

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beneficial experiences children are exposed to in learning situations involving television and computer media by adding social interaction to the media interactions themselves. In this way, the social interface can enrich the media experience in ways not possible with traditional, tool-based interface designs.

Why use physical characters as interfaces?

It is certainly possible to create social interface characters on the computer screen that behave according to social conventions and interact with users in various social ways. One example of such a technology is the Microsoft Office Assistant, which appears as a paperclip or other animated form, as part of the graphics of the Office software when the user clicks the Help icon. This character asks questions (in text printed on the screen) and can be queried in the same manner. In addition, Office Assistant also can demonstrate how to execute a given operation, literally modeling the steps to be taken as the user watches. While such graphical characters have obvious benefits, the computer screen itself diminishes the realism and lifelike nature of the interaction. The screen imposes an abstract, arbitrary ‘wall’ between the user and the interaction that limits the appeal of such interfaces – particularly for young children, whose understanding of the world is gained through the senses as much as through mental effort. For young children, a physical character offers several distinct advantages.

What do physical interface characters add to social interfaces? The most obvious factor is size and presence. Unlike the small characters on the PC screen, physical interface characters have a concrete presence. The characters described in this chapter are all 13 to 16 inches tall, or between one half and one-third the height of the children using them. Their size gives them a salience screen characters lack. In addition, their physical presence contributes to the social interactions they are intended to mimic. When physical interface characters speak to children, their voices come from their body, not a speaker somewhere on the computer’s CPU. And when they gesture, their size makes the gesture an attention-drawing event that contributes to the interface. Another advantage is having a tactile presence as well as a seen and heard one. Screen-based characters are physically removed from the user, behind a hard surface. The character interfaces described in this chapter, in contrast, are all soft plush dolls that give pleasant tactile feedback when touched. The softness is motivating to users, and encourages them to touch the characters and keep them physically close during interactions. Finally, the character’s physical presence with the child means

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that the character can exploit social strategies, such as shared attention to the computer or television, that are used in human social situations every day. Just as human social actors share a frame of reference when talking about a common object of interest (Clark and Shaefer, 1987; Grosz, and Sidner, 1986), the interface character and the child can share an implicit frame of reference when interacting around other media.

Most importantly, however, the physical presence of the interface character in the form of a plush doll invokes powerful pretend play cues common to early childhood. Young children 'animate' dolls and other objects as part of their play behavior. They treat these objects as if they are sentient and responding to them in ways that mimic familiar social interactions (comforting a 'crying' doll is a classic example) (Bretherton and Beeghly, 1989). Such pretend or "as if" engagement is a sophisticated form of dual representation, in which two levels of understanding operate at the same time. Children interact with the doll as if it is a baby but still treat it as a toy as well, adjusting it arms, standing it up, etc. (Forys and McCune-Nicolich, 1984; Herron and Sutton-Smith, 1971). Children are also familiar with puppets, and the idea of role-playing with props. By moving and talking in appropriate ways, physical interface characters invite children to participate in pretend role-playing because the characters themselves are obviously not the "real thing" they are toys. Children respond to these characters as friendly toys that they 'play along' with. When the toy is turned off, they use it as a prop for pretend play as they do any other dolls.

The nature of pretend engagement, with its dual levels of representation, is ideally suited to character interface interaction because it allows children to gracefully accommodate the less-than-realistic aspects of the interface in a playful and appropriate manner. In pretend play, children treat playthings as if they are social agents AND toys. For physical interface characters, this means that children can accommodate the interactive character's nature as a physical interface device while simultaneously engaging it as if it was a social actor. This means they are 'forgiving' of the lapses in the illusion of life that the character presents. A good example of this pretend accommodation is the way children actually interact with toy character interfaces. In most social interactions, the medium of interaction is speech. Individuals speak, listen, and respond to the utterances of one another in a shared verbal interaction. Current technology does not permit natural speech communication of this type as an input medium with technology, so a less natural, nonverbal input method must be used. Technical issues aside, there is ample

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reasons to think that a nonverbal interface will always be superior than a verbal one for very young children. While children of this age possess the ability to listen to and understand fairly complex speech from others, they do not produce such language on their own until they are much older (Bloom and Lahey, 1978). In addition, shyness or social inhibition can cause even verbally competent children to refuse to speak in social situations. A nonverbal input medium, paired with spoken and/or visual output to the child, makes the interface accessible to a wide range of users who would be excluded by any interface that depended on spoken language input.

What form should such a nonverbal medium take, particularly when the interface is a physical character? The simplest solution is to rely on the physical form of the characters themselves. A basic knowledge of the names and locations of the parts of the body is mastered by age two. This means that even very young children can competently respond to such simple interface prompts as "Squeeze my hand," "squeeze my foot," or even just "hand, hand" or "foot, foot" and engage the interface (McCarthy, 1972). By building input devices, such as touch sensors, into easily located parts of the character's body and using those locations as input media, the character's body itself becomes the input device. The dual levels of representation that contribute to pretend play, the pretend fantasy and the physical prop, makes such an interface possible. Just as children interact with dolls as if they are babies while manipulating them as dolls, they are able to interact with character interfaces as if they are social actors, but also accommodate the requirements of the toy's interface as well.

Why use familiar media characters as interface agents?

One of the most interesting phenomena involving television and other electronic media is the degree to which it fosters a sort of pseudo-intimacy and feeling of familiarity in viewers regarding characters they see on the television screen (Reeves and Nass, 1996). This "para-social" intimacy has two important effects on the character interfaces. First, the presumed intimacy of para-social relationships creates a friendly and positive disposition to the character in users. Second, the user's knowledge of the character's personality leads them to feel as if they know the personality of the character, and what they can expect from the character in an interaction. This familiarity and the expectations it creates have distinct value for interface character design because it parallels the social expectations that exist between people as

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well. Personality plays a crucial role in human social interaction because it provides a basis for predicting an individual's behavior. The consistency of an individual's preferences, attitudes, and actions over time creates a consistent set of expectations that makes the behavior of familiar individuals predictable. Even very young children have been shown to make predictions based on knowledge of personality and personal attributes (Dozier, 1991; Frye and Moore, 1991). Consistency of personality creates consistency in the social interface by making the interface character's behavior predictable as well. Children's para-social familiarity with their favorite media characters creates expectations about the interface character's behavior that are similar to expectations about another person's behavior. Accommodating these expectations is yet another way to capitalize on social processes with character-based interfaces.

A striking way to illustrate the influence of familiarity on character interfaces is to start with a look at the technology itself. Figure 1 displays the 'chassis' for Microsoft's ActiMates Barney, a physical character interface designed using the social interface model. The durable plastic housing contains a speaker, a circuit board, and a ROM chip that allows the character to speak and interact using an audio interface of pre-recorded, digitized speech. Motors in the 'shoulders' and 'neck' allow the characters to make simple movements and gestures. Sensors (visible on cables in the foreground of the picture) let children make inputs to the character, who responds with speech and motion. Note that the appearance of the chassis offers nothing that would prompt social responses in children or anyone else. Cover the chassis with a plush 'skin' however, as shown in Figure 2, and the interface becomes instantly recognizable as Barney the dinosaur, a familiar character. The physical similarity of the interface character to the television character shapes children's expectations as to what the interface character will say and do, before the character has actually been played with.

Why so much research?

The previous sections have described a theoretical and practical rationale for using physical interface characters as social interfaces for children. While applying social psychological principles to 'pretend playmate' character interfaces might appear to be a straightforward process, it is actually confounded by a variety of factors that can only be assessed by seeing children in action. The most significant of these is the impact of the child's developmental status, their social, cognitive, and motor

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skills, on the interaction. Developmental psychological research studies published in the scientific literature provide helpful insight into children's abilities at different ages, but there is no reliable way to predict children's actual responses to specific interface features. It is one thing to say that children's inputs should be made through hand and foot squeezes, for example, but quite another to decide how those inputs should be organized. Should different activities be associated with individual limbs, right hand doing one thing and the left another? Should repeated squeezes on the same sensor trigger different activities, such that two hand squeezes start one game, three squeezes another, etc.? Another key element that cannot be predicted in advance is children's reactions to and interpretations of the different elements of the interactions that the characters deliver. Consider character movement. Do children expect specific gestures to go with certain speech (moving your head as you count out loud, for example)? What sorts of movements during songs are appropriate? Are there times when movement is inappropriate because it distracts children? Only interaction with children themselves can answer these questions.

The next section presents a summary of the research and development process for three different types of toy character interfaces produced over the past three years by Microsoft's ActiMates group. Each of these toys is based on familiar media characters from popular children's programs broadcast on the Public Broadcasting System (PBS) in the United States, and each is intended for a different age group, although some overlap of ages is inevitable. The ActiMates Teletubbies, from the *Teletubbies* television program, are four different characters sharing a common interface and content design and were designed for children 1 to 4 years of age. ActiMates Barney, from the *Barney and Friends* program, is intended for children ages 2 through 5. And ActiMates Arthur and DW, brother and sister characters who share the same interface and content design, are intended for users ages 4 through 7 years of age. Each product was developed over a 12 to 14 month period, and 12 or more separate research studies, approximately one a month, were conducted on each product type during that period. (Various elements of the Barney and the Arthur/D.W. character interfaces have been described in previous articles, see Strommen 1998, 1999). The design issues that arose from applying the theoretical framework outlined above, and how the research uncovered additional issues as well as helped resolve them, are described in case studies for each product

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type. The final section of this chapter considers future applications of toy character interfaces, given advances in technology and in our understanding of social psychological processes.

Examples of physical character interfaces

Case study I: Here come the Teletubbies

The Teletubbies are four fantasy characters whose television adventures appeal to children ranging in age from less than a year old up to ages three or four. The Teletubbies are playful and childlike technological toddlers, and their behavior is deliberately meant to invoke feelings of identification from children. As characters, the Teletubbies have two specific idiosyncrasies that must be accommodated in any interface mimicking their behavior. First, their use of language is very limited. Their speech is restricted to one- or two-word utterances that sound very much like “baby talk,” the immature speech of one- and two-year old children themselves. What the program lacks in dialogue, however, it makes up for with a rich nonverbal aural environment. The Teletubbies program is filled with music and dramatic, larger-than-life sound effects of different kinds. The use of music and vivid sounds in the character’s interface along with speech raised troubling questions: Would it confuse children?

The second essential feature of the Teletubbies characters important to the interface is physical: The Teletubbies each have a television screen in their tummy. The tummy screen serves only one simple purpose for the characters on the television program. At least once per program, the Teletubbies periodically receive ‘broadcasts’ on their tummy screens. The screen then displays live action video of children and adults to the eager Teletubbies (and vicariously, to the viewer as well). In a character interface, however, a screen as part of the character’s body raises significant issues of how best to integrate the screen into the child’s interactions with the character interface itself. On the television program, the Teletubbies do no more than *watch* their own tummy screens. Could that familiar behavior be translated into the interface? Just as the Teletubbies watch their own tummy screens (and children watch with them), would children watch the character interface’s tummy screen in the same way?

The presence of the screen, combined with the nonverbal nature of the Teletubbies characters, presented a unique opportunity to combine visual and aural content in a character interface. The interactive character’s tummy screen is an actual LED display, measuring 2.5 x 2 inches, with 5mm LED lights

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organized into 8 rows and 10 columns. The lights can be turned on individually and in groups using three different colors (red, green, orange), so simple animations can be displayed in response to sensor inputs. It is known that young children detect and attend to visual and aural synchronies (Kellman and Arterbery, 1998). Providing sound effects coordinated with the graphics was presumed to reinforce looking at the screen by adding a visual aspect to character interactions. The interface model was that the child would use the hand and feet sensors to create screen-based visual effects like shapes and patterns that have nonverbal audio element such as animal noises, musical notes, and other vivid sounds (see Figure 3). This would present an exclusively nonverbal interaction to children that maintains consistency with the characters themselves as well as avoiding reliance on the language skills of the target users as part of the interface. Total speech in the entire interface consists of only 22 one- or two-word phrases. Only three of these are directed at the user: “Hand, hand!” “Foot, foot!” and “Again, again!” Yet, because the characters themselves are not particularly articulate, the social nature of the interaction is not diminished by a lack of language in the interface. The emotions in the character’s cooing, giggling, and cheering is obvious. The Teletubbies still cheer in response to child actions, coo in amazement at their efforts, and giggle at surprising or funny events caused by the children as well. As they do in their television program when they watch the events unfolding on their tummy television screens, the interactive Teletubbies characters respond to the effects of the child’s actions as they appear in the tummy LED screen.

Our first rounds of testing with a complete functional prototype supported the idea that children would squeeze the hands and feet to control events on the tummy screen. It also produced a dramatic and unexpected result. *Virtually every child, at every age, spontaneously pressed the character’s tummy screen as the first action on the doll.* They moved on to hand or foot squeezes after getting no response from the tummy, so these initial tummy attempts didn’t interfere with the interface. Why would they go right to the tummy so consistently? Queries of parents were thought provoking, because of their consistent theme of transferred expectations. One mother suggested it was because of the Tickle Me Elmo toy, a doll that giggles when the tummy is pressed. Another suggested it was because other Teletubbies dolls talk when their plush tummies are pressed, and children are familiar with them. Transfer of expectations or not, the

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pervasiveness of the behavior forced a reconsideration of the design. The screen had to become both an output and an input device.

While its inclusion complicated the design from both a hardware and software perspective, the screen's new role as an input device proved to be a boon to the interface in an unexpected way: Pressing the screen proved to be even easier to do than squeezing the hand and foot sensors, an already simple interface. The hand and foot sensors are simple pressure switches embedded in the character's hands and feet. Simple as they are, even these switches require a specific action in order to be triggered. The hand and foot switches require a controlled pincer grasp, a skill that can be attained as early as 9 months, but is usually not achieved until 18 months of age, on average (Bayley, 1969, 1993). Yet the tummy screen, also designed as a switch, proved much easier than even the hand and foot sensors. Observations of children's actions with the toy during testing indicated that the screen's surface area not only presented children with a generous, attractive target for pressing, but also was sensitive enough to support a wide variety of presses (from tips of fingers to whole hands, two hands, etc.).

The tummy sensor's popularity with children across the age span had important implications for content design. Accommodating its broad appeal required that it be dedicated to a single, popular activity -- an activity simple enough that infants could understand it, but also appealing to older children. The choice was animations set to music. Tummy presses result in brief animations, set to familiar children's tunes played using different instruments (no songs have words, due to the limited language of the Teletubbies themselves). One tune plays with each press of the tummy sensor. Rapid presses cycle through the tunes, so specific selections can be located on demand. In testing with children, this feature proved very popular. Children two and three years old were observed using the repeated squeezes to 'jump' specific tunes they did not like, as well as cycle through in order to find tunes they did like. The tummy thus becomes a digital jukebox, a function that spans the wide age range of intended users.

The screen received the most attention because of its surprise transformation from output device to both input and output medium, but once screen functionality was settled, there was still the question of what to do with the hand and feet sensors. What should the interactions supported by these sensors be?

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Should they be divided by limb, hands dedicated to one thing, feet to another? Should each hand and foot be dedicated to one of four unique functions, or should they all contribute to one single activity together? The simplest and most consistent solution was to have all four limbs be part of the same function. By using all four limbs in a similar manner within a given game, their integrated nature would be made clear to children during their interactions, encouraging them to see the hands and feet as part of a single activity. In keeping with the nonverbal, visual nature of the content, the hand and feet sensors were used as controls for selecting the color of portions of the screen, or to advance a growing form as it is draw in, step by step, with each squeeze. Grouping the sensors in this way meant that despite having five distinct sensors, the Teletubbies interface really consists of just two choices: Songs (tummy sensor) or games (hands and feet). Movement within and between these two types of content constitutes the entirety of the interface. Such a simple, binary choice is ideally matched to the nascent cognitive skills of the very young children who are the intended users.

The Teletubbies design illustrates how a physical interface character can integrate character attributes with user expectations to create an engaging interactive experience. The reactive and childlike nature of the Teletubbies television characters themselves defined the social role of the characters during interaction. Just as the television characters watch their own tummy screens, the Teletubbies characters react to the effects of the child's actions on their own tummies with coos, cheers, and other responses. The tummy screen itself added new functionality to the character interface. It not only allowed for a graphical, nonverbal output medium appropriate to pre-verbal users to be added to the design, but observations in early testing of children's responses to the screen helped define the interface itself. Dedicating the tummy to one simple, popular function while using the hands and feet together as part of a different, more complex function creates a contrasting set of options that matches the abilities of both the low end (infants) and high end (preschoolers) of the user population.

Case study 2: Barney the dinosaur

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The Teletubbies interface emphasizes explicitly graphical elements and nonverbal audio effects like musical notes and animal sounds, while downplaying the use of language. Such a strategy is consistent with both the philosophy of the television program from which the characters originated, as well as with the intellectual skills of the intended users. A different character and different educational emphasis, however, can change the interface dramatically -- even if the target age group is largely the same. Change the media character's relationship to the user from that of a toddler-like peer to one of a parent-like adult, for example, and the nature of the interactions changes as well. This is especially true when the educational goals of the character's television program, in this case *Barney and Friends*, is explicitly concerned with using language as a means of expression. Add the absence of a visual interface like the tummy screen, and it becomes clear that the use of speech, minimized in the Teletubbies interface, becomes the key to the entire interface design.

An emphasis on spoken language is consisen with the educational philosophy of the *Barney and Friends* program. Speech figures prominently not only in the television program, but also in its associated books and CD-ROMs as well. In all these media, Barney is cast in the role of a gentle, encouraging authority figure who does a lot of talking as he leads, guides, explains, and directs the behavior of children on the program. Also unlike the Teletubbies, whose nonverbal nature meant that their musical interactions had to be instrumental only, Barney's musical activities all involve the use of sung lyrics. The deliberate use of language as a medium for promoting learning is drawn from a well-established theoretical and empirical tradition in developmental psychology and pedagogy that emphasizes the power of language to not simply communicate ideas, but actually shape thinking itself. In this model of learning and mental growth, the semantic and syntactic structures of language, and the social processes by which they are imparted to children, are thought to organize children's thinking. The mastery of language is akin to the mastery of reasoning itself (Diaz and Berk, 1992; Vygotsky, 1978). What would be the most developmentally appropriate way to apply this model of mental growth, and all the speech that goes with it, to a Barney the dinosaur character interface? The challenge for this interface was to create an appealing set of interactions

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based primarily in language, interactions that accommodated the same range of cognitive and motor abilities covered by the Teletubbies interface, but that exploited rather than avoided verbal content.

What to say and when to say it

Barney's speech was scripted to both preserve Barney's own characteristic verbal style and also to accommodate audio interface design principles. In terms of style, Barney's interface speech is always conversational and familiar. He refers to the child using the pronoun "you," and to their joint activities using the shared pronoun "we." Special attention was paid to Barney's idiosyncratic speech patterns, and replicating them in the interface itself. Barney is polite, for example, so in his interface speech he uses the words 'please' and 'thank you' during interactions. He also has distinctive exclamations, such as "Super-de-duper!" or "Stuuupendous!" and frequently gives praise and expresses affection. These traits were deliberately preserved in the audio interface. Every game and song ends with praise for the child and expressions of pleasure on Barney's part, for example. Random 'friendship' phrases such as "I like playing with you!" and "You're my special friend!" play in the interface during idle moments, giving the appearance of spontaneous statements of affection. In user testing with prototype characters, children reacted very positively to these features of the audio interface, often hugging Barney after hearing such phrases or moving the character physically closer to themselves.

In terms of audio interface design principles, several relevant aspects of how such language should be scripted can be found in the research to date, most of it focused primarily on adult users of telephone interfaces (see the review by Resnick and Virzi, 1995). A critical issue, for example, is brevity: Speech output should be composed of brief phrases, rather than lengthy sentences. Long speech segments tax the limits of users' sequential memory, causing them to forget part of what they heard. This problem is exacerbated in young children, whose memory capacities are even smaller, relative to adults (Case, 1985). In terms of style of speech, research on adults using phone interfaces has found that open queries (for example, "What would you like to do now?") prompt user responses less often than do explicit directives such as "To place a call, press 1 now." These two findings concerning brevity and the value of directive

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speech have also been reported for preschool children using talking software (Grover, 1986; Strommen, 1991). Building on these findings, Barney keeps his comments short and does not ask open-ended questions as part of his verbal interface. Instead, he makes simple directive statements such as: "Cover my eyes to play Peek-a-boo!" or "Squeeze my middle toe to sing a song!"

As another humanoid interactive character, the hardware interface for Barney would obviously share a 'family resemblance' to the Teletubbies design, with sensors located in specific parts of the character's body as the mechanism for the child to use to register inputs (see Figure 2). Just like the Teletubbies, Barney has five sensors. Four are pressure switches located in his hands and feet, just as in the Teletubbies. The fifth sensor, however, was unique: A light sensor located in the character's eye that registers changes in light level. As would be expected, the same issues raised by the Teletubbies interface, such as how to assign functions to the different sensors and how many functions there should be, had to be addressed for Barney as well.

The strategy finally adopted for the interface was to segregate Barney's different functions by sensor location on his body. In the Teletubbies design, the distinction among sensors was limited to screen (music) vs. games (hands and feet). In the Barney interface, functions are associated with each place where a sensor is located on his body: In the feet, hands, or eye. Barney's feet are dedicated to songs. Squeezing the touch sensors in either of Barney's feet causes him to sing one of 16 familiar preschool songs (*The wheels on the bus*, *If you're happy and you know it*, and so on.). Barney's hands are dedicated to activities and games. Squeezing the sensors in either of Barney's hands causes him to randomly do one of the following: recite nursery rhymes, pose simple queries that require no response ("Is it raining outside? I like rainy days and sunny days!" and so on), or engage the child in an imitation game using animal sounds or simple motor movements. There are a total of 12 different interactions in all. Barney's eyes are dedicated to the game of peek-a-boo. Peek-a-boo was designed as an open-ended series of alternating "It's dark" / "It's light" responses. When Barney detects a loss of light, he responded with an 'It's dark' comment such as "Where did everybody go?" "Now I can't see you!" or "It sure is dark!" After playing an "It's dark"

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comment, when Barney detects an increase in light, he responds with an "It's light" comment: "Peek-a-boo, I see you!" "Oh, there you are!" and so on. The effectiveness of dedicating sensors to functions based on their location on his body was assessed by having children return repeatedly to play with Barney over several months, for different studies. When children returned, they were asked to make Barney sing a song, play a game, or play peek-a-boo. The results were striking: even after just a single session, most children recalled exactly which sensor started a given function, and executed it confidently and reliably.

In the Teletubbies interface, all four hands and feet are used in game play, but each hand and each foot contributes to the games in a unique way. The left hand and right hand, for example, each control a different color or a different portion of the screen. The visual interface supports this diversity of function by letting the child see the effects of different sensor inputs directly on the screen. Children do not have to know left and right to grasp what the sensors do, because they receive concrete visual feedback from their actions on the screen. In Barney's interface, in contrast, there are only verbal, not visual, cues to assist in identifying the left and right hands. Given the fact that left and right are not reliably distinguished by children in the target age range (McCarthy, 1972), it was decided that the two hands should be redundant with each other, as would the two feet. This redundancy achieved two goals: First, it simplified the audio interface. Barney could say “Squeeze my hand to play a game” instead of “Squeeze my LEFT hand to play a game.” Second, it meant the child could grasp either hand and be guaranteed of a game. The chance of confusion over different functions in the different hands was thus eliminated.

The Barney character interface has one additional complexity that the Teletubbies interface did not: Movement. In Barney's design, unlike that of the Teletubbies, motors located in the character allowed for simple but expressive head and arm movement. Movement was an important addition to the interface. In his television program, Barney is very physically active, frequently engaging in such activities as dancing, running around, and jumping up and down. Physical movement is thus a key element of Barney's character. More concretely, early testing of Barney's design had revealed that movement by the character had a surprising and powerful effect: It drew and held children's attention in ways that speech alone did

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not. The movement was particularly effective during singing. In testing with singing interactions, repetitive movements by the character during choruses of songs actually prompted children to mimic the character's actions and dance along themselves. Movement during games and during peek-a-boo enhanced the content of these functions as well, but also created an unexpected complication: In certain games, the movement could actually interfere with the child's performance if it occurred at an inopportune moment. The problem stemmed from the fact that the head and arms were not just part of the output, being the gestural complement to Barney's speech. Because of the sensor locations in the hands and eyes, the hand and arms also served input functions as well. Observations during user testing indicated that during games that required repeated hand squeezes such as counting (where Barney says a number with each squeeze), if the arm moved as he counted children had trouble 'catching' the hand to make their inputs. Similarly, if Barney's head moved while his eyes were being covered by the child, he would inadvertently cause his eyes to be uncovered and disrupt the game. To prevent these difficulties, Barney's head and arm movements for each activity were carefully choreographed so that, for example, he did not move his arms or head at the points in the interactions where they were needed as input devices.

The differences between Barney's interface design and that of the Teletubbies demonstrates the ways that both personality and curriculum can have a significant impact on the nature of the character interface's design and interactions, even when the target age group is basically the same. Both interfaces have five sensors, four of them in the hands and feet. Both interfaces also use sequential, repeated squeezes of the sensors as the means of making inputs when interacting. Yet the Teletubbies interface is simpler, offering but two options (music and games), while Barney's interface offers three (songs, games, and peek-a-boo). More significant from the point of view of character social interface design, however, is Barney's reliance on language and gesture. The speech and motion included in the interface had to address multiple goals. It had to be true to Barney's character in style and content while simultaneously following known interface principles. More importantly, it also had to match the limitations in young children's abilities to understand and respond to language, as well as the limitations of their immature cognitive abilities. Accommodating these limitations led to an interface that, while successful for its users, was restricted in

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the complexity of interactions it could support. As development progresses and the developmental limitations in children's competence wanes, however, it becomes possible to use the same basic interface to support interactions of much more sophistication.

Case study 3: Arthur and D.W.

The Teletubbies and Barney the dinosaur are characters who appeal to very young children, typically children under the age of five. The trajectory of child development is such that this brief span of time sees children progress from acquiring basic motor skills and thought processes in infancy through the acquisition and mastery of language, and the orderly thinking language imposes. Social skills undergo a similar dramatic transition as well. Children progress from the egocentrism of infancy to being able to interact cooperatively with others, both children and adults, and to collaborate on activities like games or shared pretend together. The climax of all of these changes is a new level of basic competence in thinking and doing, and new strengths in interacting with others. These advances mean new opportunities and new challenges for character interface designs. Older children can clearly do more and think in more sophisticated ways than their younger counterparts. What sorts of characters and what sorts of interactions are possible for children older than five years of age?

Meet Arthur and D.W.

Arthur and D.W. are fictional siblings, the literary creations of children's author Marc Brown. They have been familiar to American children for more than 15 years as the central characters in more than 30 children's books, a popular television series, and several educational CD-ROM titles intended for the four- to eight-year-old population. Arthur and D.W. are anthropomorphized aardvarks who live in a suburban neighborhood with other animal families. Their animal-like appearance notwithstanding, Arthur and D.W's behavior is completely human. What is more, their abilities and interests, their language use, and their behavior is typical of that of the older children who are their target audience. These personal attributes create new opportunities for more sophisticated interactions than those created for younger children in the Teletubbies and Barney characters.

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The new level of sophistication possible with these characters and the older children to whom they appeal is manfested in a very concrete way in the hardware interface. While Barney and the Teletubbies have five sensors, Arthur and D.W. have seven: Two in the hands, two in the feet, two in the ears, and one in the watch on the character's left arm (see Figure 4). As Barney and the Teletubbies demonstrated, the number of sensors is not a direct indicator of interface complexity, since both of those interfaces have five sensors but differ in the quantity and type of content they support. The more sensors available in the interface, however, the more opportunities there are to create more and deeper levels of interaction because more sensors provide a broader range of input options. The wider content design possibilities of more sensors notwithstanding, the fact that the interface is a character and that the sensors are still associated with their locations in the characters' bodies places certain constraints on how they can be used in interactions. While the user population is more sophisticated than the preschool population that was the focus of the Barney interface design, certain developmental limitations remain. Left and right identification are still not firmly established in a majority of children at this age, for example, so diversifying the sensors by left and right still has to be avoided (Clark and Klonoff, 1990). For reasons such as these, Arthur and D.W.'s interfaces do not represent a dramatic departure from the Barney or Teletubbies designs so much as a new strategy for using such interfaces as a means to control interactions. This strategy maintains a high degree of simplicity, but still capitalizes on the competencies of the older children who are the intended users by using the sensors in both the same and different ways at the same time. The result is an interface that has a strong "family resemblance" to Barney and the Teletubbies, differing from them in degree, rather than kind.

The Arthur and D.W. interface

As with Barney, the content of the Arthur and D.W. characters is segregated by sensor location. Just as there are three types of function supported by Barney's three sensor locations (eyes, hands, and feet), Arthur and D.W. have three functions as well, associated with the ears, watch, and feet. The interface differs from Barney's in two ways. First, there is an extra set of sensors, located in the hands, that are not

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associated with any specific function. This is because their role is to be used in conjunction with the other sensors, to allow for more complex interactions in those functions than a single sensor permits. Second, sensors do not remain dedicated to one single purpose during all interactions. This is the key design difference between Arthur and D.W.'s interface and the Barney and Teletubby interface designs. The Barney and Teletubby interfaces rely on no more than sequential inputs on the same sensor as a means of engaging content (repeatedly squeezing the hand to play serial games such as reciting the alphabet, for example, or repeatedly covering and uncovering the eyes to play peek-a-boo). In Arthur and D.W.'s interface, in contrast, games are initiated using one sensor but once a game is started, a variety of sensors (the hands as well as others) are used in actual game play. How is this multiple-sensor interface, where sensor functions actually change depending on context, laid out? In a way that both resembles and departs from the Barney model.

Ears are to hear what Arthur and D.W. are thinking. Squeezing the ears allows children to "eavesdrop" on Arthur or D.W.'s thoughts. Each ear squeeze plays one of dozens of unique phrases that ask questions, offer opinions, share jokes, and give compliments. The content of these phrases is scripted to reflect the individual thoughts and feelings of the fictional characters Arthur or D.W, and are consistent with the social and emotional themes central to the Arthur stories and television series on which the characters are based. The comments also reflect the interest and ideas of children in the target age group, as uncovered in our research and in reviews of the existing psychological and educational literature. Such 'thoughts' are particularly well suited to a character interface, with its explicitly social nature. The phrases spoken in response to ear squeezes fall into several categories:

Jokes. Arthur and D.W. share silly ideas or comical events with the child. Arthur, for example, says "You know what's gross?" and then proceeds to name something silly, such as "sweaty gym socks," that elicits humorous reactions of disgust from the child.

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Secrets. Arthur and D.W. say, “Come closer, I want to tell you a secret!” and then confide an embarrassing fact or a private opinion to the child.

Playful Teasing. Arthur and D.W. make mock requests or gently tease the child with information they know, such as the child’s birthday.

Compliments and affection. Arthur and D.W. both express affection for the child, through such comments as “I’m lucky to have a friend like you!”

Speculations about future careers. Both characters reflect on possible adult career roles, asking “What should I be when I grow up?” and then answering their own question with a speculation. Arthur, for example, says “Maybe I’ll be an astronaut and discover a new planet!” Reflecting her more ambitious and gregarious nature, D.W.’s speculations are more grandiose, for example “Maybe I’ll be President. You can be my vice-President!”

In the case of ear phrases, the hands function as a reminder and memory aid. If the last input before the hand was squeezed was an ear squeeze, squeezing the hand sensor results in the character’s repeating the last ear phrase so it can be heard again on demand.

The watch is for telling time. It is in the four to eight year old age range that most children acquire their first wristwatch or alarm clock, and when an interest in time and calendar knowledge first appears. Arthur and D.W. support this interest by acting as a sort of smart friend, who always knows the time and date. When their watches are squeezed, the characters say the current time, date, and day of the week. If the date is a holiday, the character announces that fact along with the date. The characters can also be programmed to know a specific birthday, and will treat that date as a holiday. They can also be programmed as alarms, allowing them to wake the user in the morning or remind them that it is a specific time. The fact that they report the time verbally means that even children who cannot read clocks accurately can know the time

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when they want to know it, just as if they had asked an older peer or parent. The time and date features thus make Arthur and D.W. seem like friends who are not only intelligent, but supportive and empowering as well. In testing of this feature, for example, it was common to observe children comparing their own watches with the time reported by the characters, checking their own accuracy and using the characters to assist them in mastering the skill of reading a clock face. Several children even took the reverse approach, using their own mastery of time skills to check the accuracy of the character, nodding approvingly when the character's time matched the time on their watches or re-setting the character's time if it did not.

The hand sensor plays the same complementary role to the watch that it does for the ear. If the last input before the hand was squeezed was the watch, the character repeats the time.

Feet are for games. When a foot is squeezed, the characters play games. Both Arthur and D.W. play the same games. While there are 10 different games the characters can play, several are similar to those of Barney, and require only sequential squeezes of the same sensor to play. The games of particular interest to this discussion, however, are those that utilize more than one sensor during play, giving the user more options but also requiring more from the user as a result. There are several of these games:

Guess the holiday. The character gives a date and asks the child to name the holiday that falls on that date. A hand squeeze reports the answer. A second hand squeeze repeats the previous date and holiday. An ear squeeze causes the character to present a new date to be identified. A foot squeeze aborts this game and launches a new game.

How Long Is That? The character challenges the child to estimate a specific length of time (5, 10, 15, or 20 seconds) and squeeze a hand sensor when the duration is passed. Squeezing a hand again restarts the game again with the same target time. Squeezing an ear restarts the game with a different target time. A foot squeeze aborts this game and launches a new game.

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The Memory Game. In this game, children memorize, then execute, progressively longer lists of sensor squeezes (“Hand, foot, ear, ”). Each time the list is correctly input using the character sensors, a new element is added to the list on the next round, until an error is made. A foot squeeze aborts this game and launches a new game.

Silly Sentences. The character combines randomly selected adjectives, nouns, and verbs to create nonsense sentences such as “The jiggling wombat does the cha-cha with the stinky antelope!” Squeezing the hand repeats the same sentence, squeezing the ear results in a new sentence. A foot squeeze aborts this game and launches a new game.

Tongue twisters. The character challenges the child to say a tongue twister, then waits as the child recites it. A hand squeeze repeats the tongue twister, an ear squeeze results in a new tongue twister. A foot squeeze aborts this game and launches a new game.

The ‘nested’ functions requiring hand and ear inputs within these games have two characteristics intended to make navigation by users easy and understandable. First, the foot sensor keeps its “pick a game” function, even within games. Thus repeated squeezes of the foot always allow the user to select a different game at any time and foot squeezes always end an active game and start a new one. Second, the hand and ear sensors each have a consistent function across games. The ears let users select a new round of a game with new content, while the hands repeat the same round. The use of such consistent rules alleviates much of the risk of confusion that re-assigning sensor functions can create, by making sensor actions, even changes in their functions, predictable to children in all contexts. In user testing, it did not take children long to recognize and use these basic conventions to navigate among their choices in the interface, underscoring the advanced competence these older children possess relative to their younger peers, whose abilities required far simpler and more strictly consistent interface rules.

Personality and the older child

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The deeper and more complicated interface functions intended to match the capabilities of the older children who are the users of the Arthur and D.W. characters are matched by a more varied and subtle design of the social interactions of the character as well. The social interface for the Teletubbies characters are deliberately simple: The characters greet the child, and react to the child's inputs using simple, affective responses such as cheering or cooing with admiration. Such responses are not only developmentally appropriate, but are also in keeping with the personalities and social interactions of the Teletubbies themselves on their television program. Barney's social interactions are slightly more complex, owing to both his own personality and his use of simple language in the interface. Barney not only reacts to the child's inputs with pleasure and eagerness ("That was fun!"), but is also encouraging ("Now YOU try it!") and affectionate ("I like playing with you!").

Arthur and D.W.'s emotional interactions, similar to their game interactions, are more sophisticated than those of Barney and the Teletubbies. Like Barney and the Teletubbies, they respond with pleasure and enthusiasm to the child's input, and like Barney they are explicitly encouraging of the child's efforts. But they also utilize language to engage in more subtle emotional interactions as well. Arthur makes humorous yet self-effacing comments about his appearance, saying for example "Are my glasses on straight? I don't want to look goofy!" The reaction of children during testing was one of sympathy. They often adjusted his glasses, in effect helping him make sure he looks good to others. D.W. expresses a similar sentiment and elicits a similar reaction. When D.W. says plaintively "I'm having a bad hair day!" children of both genders responded to her in some manner. Girls in particular frequently began grooming D.W., combing her hair with their fingers. Both characters also speculate about their own adult careers, modeling confidence and curiosity about the future and both conspire with users, sharing secrets with them. All of these interactions mimic the content of social interactions the child would likely have with a same-aged peer.

Beyond these general emotional interactions, the increased complexity of Arthur and D.W.'s games also requires a more sophisticated use of emotions during game play. How Long Is That (HLIT) and

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The Memory Game (TMG) are the two most challenging games Arthur and D.W. play. Both games require sustained effort and repeated trials for success, meaning that failures are frequent. In HLIT, for example, children can repeatedly try to estimate the duration of 10 seconds and be wrong again and again as they refine their performance. Even with repeated trials, success is not guaranteed. In TMG, the situation is similar: The list of items to be remembered gets longer and longer with each round, guaranteeing that it will lengthen beyond children's competence as they repeatedly challenge themselves during game play. In the initial designs for both games, failures were not overtly acknowledge by the characters. A failure, such as making the wrong input when recalling the items in TMG, simply led to a new round of the game immediately after the error was confirmed. The character simply said "Oops, that's not it!" or a similar phrase, and then said "Let's try again!" Children's reactions to this transition from failure to a new round were striking: They often looked down or looked away from the character, and interacted less frequently with the character for several minutes afterward. Based on this observations, the design of these games was changed such that, after an error was confirmed ("Oops! That's not what comes next!"), Arthur and D.W. praise the child's effort ("That was hard!" or "That was a tough one!") prior to starting the new round. In subsequent testing this sympathy from the character seemed to soften the blow by acknowledging the difficulty of the task. True or not, the decline in positive affect and interaction that had accompanied failures without the comment were not observed during that game in subsequent prototype testing.

Social interfaces and media convergence

In the previous case studies, the design of three physical character interfaces were described. While they are each distinct products, several common themes cross all their designs. The first is the importance of personality for the interface. This is particularly true with characters from television programs. The intimate nature of television is such that children feel they are familiar with the characters they are viewing, even if they have never interacted with them physically, but simply watched them on the screen. Simply put, they know the character represented in the interface. They have expectations about

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character behavior, speech, and personal preferences that the interface character must meet in order to hold the user's attention and interest. The second theme in the design of the characters is the importance of understanding the children in the different age groups who are users of the products under discussion. Existing research data on children's social and cognitive competencies in the target user ages, as well as actual tests of child users with the interfaces themselves, were used to inform both the interface design and the role of language in it. Playing to children's strengths in social skills while avoiding the weaknesses in their cognitive and linguistic abilities (such as literacy and attention span) requires careful design and evaluation. When personality and user abilities are combined correctly, the result is a successful social interface design for children.

In the free standing play described for the above products, the child interacts directly with the character. The social nature of the child's engagement with the character interface was conceived as similar to one-on-one peer play, a two-way exchange or dialogue, and the interactions of the characters reflect this one-on-one relationship in specific ways. For example, the character reacts to the child's actions with verbal and nonverbal responses that assume a shared experience: They use personal pronouns such as "you" when referring to the child and "we" when referring to shared play activities. In the case of the Teletubbies, who do not use pronouns, their one- and two-word comments are scripted as reactions and exclamations directed to the child. Not all social interactions are one-on-one interactions, however, and the social rules for different types of social interactions are different, depending on the nature of the interaction. One factor that exerts a significant influence over the rules of social interaction is the presence of different forms of media in the social context. The social rules for sharing such activities as using a computer together or watching television together differ from those deployed in a one-on-one social exchange (Huston, et al., 1992). By adopting the appropriate social rules for these interactions around other media, pretend playmate interfaces are able to play a role in children's media interaction beyond the role they play as pretend playmates by themselves. In this section, the nature of pretend playmate interaction with both broadcast and interactive media will be described.

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Interaction with the television

The key element in social interaction with other media is the ability to respond to the new media content in appropriate ways. Interactions around a television or a computer have the media content as their primary focus. Social exchanges around these media forms are responses to the media content itself, rather than responses to the actions of users. Shared television viewing, for example, is largely a matter of sharing reactions to the events on the screen (Huston, et al., 1992). Such interactions are more than idle banter, however. Research on learning from television has established that young children comprehend more program content when their viewing is supplemented by the comments and questions of older peers or adults than when they simply view alone (Collins, Sobol, and Westby 1981; Haefner and Wartella 1987; Huston, et al, 1992). These social interactions around the television, described as 'co-viewing,' are ideal candidates for character interaction because they are almost completely verbal: The children's eyes are on the television screen, but they listen to and respond to the utterances of others watching along. The character's physical presence sitting with the child actually reinforces this social script. Another practical reason why such interactions are ideal is that the presence of the television provides a common focus of attention for both the child and the character. By structuring the interaction as one of sharing reactions to the same experience, the character's verbal comments can be context-specific, because they are reactions to the content of the program itself.

But how does the interface character know what is on the television? The character must interact with the television in some manner, and the exact nature of the interaction has serious implications for the integrity of the interface's pretend playmate-like nature. The form of interaction with the television itself is subject to social expectations, just as the content of the character's interactions are. If the characters had to be physically plugged in to the television, for example, the social repercussions would be significant. Not only is the use of a physical interface like a wire clumsy and artificial, destroying the pretend scenario of life-like behavior on the part of the character, but it also has the practical effect of restricting the physical location and use of the character itself. The wire imposes a limit on how far the character can be moved around the TV, for example, and the child must accommodate it in order to use the interface. It also creates

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an artificial transition into and out of the viewing experience, requiring the child to not only plug the character IN so that viewing can be shared, but also requiring the child to UNPLUG the character at the end of the viewing experience.

What would be a more natural (i.e. social) way to engage television content? Human viewers make the transition from not viewing to viewing very easily and transparently, simply by shifting their attention to the television itself and responding to what they see and hear. Socially-based character interfaces should do the same, if their goal is to mimic social behavior and maintain the social pretense that is the basis for the interface itself. In practical terms, this means that whatever the interface between the character and the television, it should be invisible to the user and the transition to watching the television should be as simple and easy as it is with a peer: turn on the television and start watching. Clearly, these constraints all dictate a wireless interaction, but a lack of a physical interface like a wire alone is not sufficient, since wireless interactions can also impose their own demands on users. Consider an infra-red (IR) interface, like a remote control. It is wireless, but it has an added constraint of requiring a direct line of sight between the character and the IR transceiver. Given the unpredictable positions the character might be placed in (lying down on its back, sitting at an angle, etc.) and the uncertain location of furniture relative to the television, IR interaction is still too limited. The child would be required to position the character in specific ways, another odd and unnatural addition to what is supposed to be a familiar and simple social interaction.

The ideal interface between the character and the television, therefore, is one that is not only wireless but that does not create arbitrary functional restrictions of its own, either. The medium that meets all these criteria is radio-frequency (RF) interaction. All of the characters discussed in this chapter interact with other media using RF as a medium. Each character has an internal radio transceiver similar to that of a walkie-talkie that is integrated with the character's other free-standing functions. When a special transmitter is attached to a TV and VCR, new speech and motion for the character on specially encoded tapes and broadcasts of video programming are transmitted to the character in real time while the program

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is being viewed. When the characters detect the transmitted information, they give a brief comment (Barney says "Let's watch TV together!" for example, and Arthur says "Hey, look who's on TV!") and then begin to interact with the program. The real-time interaction with the new content broadcast from the television transmitter allows the characters to respond to the content of the programs in context-sensitive ways, such as singing along with a tune or reacting to onscreen events with context-specific phrases. When the program or tape is over and the signal from the transmitter ceases, the characters make a transition comment indicating they are no longer watching TV (Barney says, for example, "That was fun!"), and free-standing play functionality resumes.

The co-viewing interactions with the television during the broadcast are scripted to match the personality of the character and the developmental status of the child, just as the one-on-one interactions are. The goal of these interactions, like those in one-on-one play, are to engage the user cognitively and emotionally in educational activities. The only difference is that now, instead of interacting with the character interface directly, the child is being directed to the video broadcast content. Each of the different types of characters use different, character-specific interactions to achieve this goal. For the Teletubbies, interaction with the television is based on the notion that the Teletubbies themselves are children's peers. They participate in the program using language appropriate to the Teletubbies characters, and their participation involves using speech in ways that are consistent with the behavior of the Teletubbies themselves. They either repeat speech on the program after it is said or they say familiar phrases along with the characters on the program at the same time, creating a sort of chorus. If the character on the screen says "Bye bye!" for example, the Teletubby character watching with the child says "Bye bye!" in response. If the Teletubbies on TV all say "Uh-oh!" at the same time, the Teletubby character says "Uh-oh!" along with them. The Teletubbies react with giggles and cooing to onscreen events in the same manner. The Teletubbies also play music when the Teletubbies on the screen dance to music. The same music as on the program plays out of the Teletubby, in synchrony with the music on the television. Testing of these types of interactions confirmed that they engage children in the program content. Children often repeat the phrases said by the characters, for example. They recite familiar lines along with the characters on the

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program more often when the character is present than when viewing without the character and, most striking, the music played from the character prompted children to actually dance along, holding the character in their arms, a behavior seen very infrequently without the pretend playmate character present. These heightened levels of participation and engagement increase children's understanding of and enjoyment of the program.

Barney, Arthur, and D.W.'s interactions with their programs are more complex and utilize their more sophisticated language, but they too respond to the program in ways that reflect their co-viewing social role relative to the child user. Like the Teletubbies, their interactions are intended to enhance viewing and the child's participation in program content. Their methods of doing so, however, are different. Unlike the Teletubbies, for example, Barney is not a peer for children but more of a parental figure. While he reacts to events onscreen (chuckling at humorous situations, for example), he also anticipates them, saying things like "Oh, look!" to draw children's attention to onscreen action. His comments are also more tutorial in nature, in keeping with his role as guide and authority figure. What he says are phrases shown to stimulate thinking in children. Barney asks questions ("What do you think will happen next?"), he labels onscreen images using appropriate vocabulary ("That's a square!"), he counts along with onscreen characters, and he sings along with songs, reciting the words. He also cheers, laughs, acts surprised, and has other emotional responses to what is onscreen. In testing, these interactions were very effective in prompting responses from children in return. They frequently answered his questions, for example, and often began singing along with a song after hearing Barney sing the chorus once.

What about Arthur and D.W.? Like the Teletubbies, Arthur and D.W.'s social role relative to the child user is that of a peer. The older age of their target users, however, gives their peer exchanges a much different meaning than it does for the Teletubbies. The goal of Arthur and D.W.'s television interactions is to engage the children in thinking about and reflecting on the social and emotional issues that are the central themes of the program itself. The two characters do this by making their own personal comments about what they are watching, comments that state a specific personal reaction to what they see. While

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watching a segment where Arthur is being teased, for example, the Arthur character interface might say "I hate this part!" in an embarrassed tone of voice as he watches himself being made fun of. D.W. watching the same segment, however, responds differently. Instead of identifying with the awkward embarrassment her brother feels, she reacts more aggressively, criticizing the teasing comments with a scolding "That's not nice!" The design strategy behind such interactions is to get children to reflect on their own responses to what they are watching. The idea is to get the child to think 'D.W. said how she feels. What do I feel?' Arthur and D.W. are modeling engagement with the emotional content of the program. Testing of these segments with children confirmed that they elicit the appropriate reactions. One response to the Arthur character's embarrassment, for example, was that children tended to hug the doll or comfort him after it spoke. This response suggests that the children registered the emotional message Arthur was conveying.

The fact that the goal of television interaction is to engage children in program content, rather than with the interface character, itself raises a critical issue for video interaction: What functions should the character's sensors have during television interaction? The linear nature of video content, and the episode-specific content of each program, mean that the character's normal play functions cannot remain active. If they did, then depending on the character, actuating a sensor would launch a game with its attendant sounds and/or graphics or start a song or tune. These games and music would be unrelated to the program content and would create a distraction, drawing children's attention away from the program rather than keeping them interested in it. But what alternative designs would be better? One possible solution is to simply deactivate the sensors during TV viewing. This would mean that the characters would comment on what was being watched, but would not respond to children's actions if the sensors were squeezed. A test of this scenario showed it was inappropriate. Children acted on the character's sensors very infrequently, but when the characters failed to respond the children were perplexed. Why was the character talking (commenting on the program), yet not responding to their actions as it had before? The character's lack of responsiveness actually became a distraction in itself, as children turned their attention to the character and tried to elicit a response, ignoring the content of the program they were viewing.

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The design strategy for sensor functions in TV viewing originated in a careful review of how children interacted not only with the interface character but also with their parents during TV viewing. Unlike their interactions with the characters in freestanding mode, children did not give their full attention to the characters when they interacted with them in TV mode. Rather, they tended to reach over and act on the character absently, as a secondary behavior during viewing. Their eyes usually remained onscreen. What was striking was that they tended to act in the same manner on another person watching along with them, *often with an identical action*. If during a Barney episode they patted their parent’s arm while viewing, for example, they also patted the Barney character. It was the response of the parents and siblings that provided the design for the character’s response. Their responses to being touched were typically no more than brief recognitory actions (a return pat, a stroke, a verbal comment, etc.). This type of response typically satisfied the child viewer and further interactions ceased. Would children be satisfied with a similar, abbreviated response from pretend playmate characters?

Subsequent testing revealed that this was in fact the case. If the children squeezed Barney’s hand or foot, for example, all he had to do was make a friendly comment (“I like watching TV with you,”) or give a generic, TV-specific attention directive (“What’s happening on the TV?”), and children were content. No children protested or asked why Barney did not play games or sing while watching TV if his hands or feet were squeezed. This basic design was tested and found to work with the Teletubbies (who giggle in response to sensor inputs) and with Arthur and D.W., who make comments similar to Barney’s (“Are you trying to get my attention?” or “This is my favorite show!” etc.)

<u>Interaction with the PC</u>

Television interaction is limited by the fact that the while the character interacts with the child through its reactions to the program content, the child’s inputs to the character cannot affect the program content. Nor can the child’s actions on the character influence the character’s behavior in any meaningful way without risking distracting the child from the program. Interaction with computer technologies, however, is a different story. When an RF transmitter is attached to a PC running encoded CD-ROMs or using a web browser with specially encoded web sites on the internet, the characters can both receive new

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speech and motion content from the computer AND transmit inputs from their own sensors back to the computer as well. In this way, the characters not only react to children’s actions as they use the computer with a keyboard and pointing device, but children's actions on the character’s sensors also affect what happens on the computer as well.

As with television interaction, the critical design issue was choosing what social rules and social role the characters should have at the computer. The Teletubbies characters, designed as they are for very young children, do not have PC-related interactions as this chapter goes to press. However, Barney, Arthur and D.W. interact with specially encoded CD-ROMs, and Arthur and D.W. interact with the Arthur website at www.pbs.org. What sorts of interactions are appropriate for pretend playmates during computer interaction, and how does the social role of the character shape the content and style of those interactions? The first step taken in shaping the interactions at the computer was to review the literature on children working together at the computer (Johnson and Johnson, 1975; Mevarech, Silber, and Fein, 1991; Nastasi and Clements, 1992; Slavin, 1980). These studies provided insight into the dynamics of situations where social interactions take place around the computer as the common focus of attention. This research also documented the types of verbal interactions used by peers, especially thinking aloud during task execution, praise, and hints, which are most effective in promoting learning and mastery. The literature on computers and learning did not, however, provide insight into how physical character interfaces, as simulacra with their own input sensors, should be integrated with the computer. Was it possible to create computer interactions that combine sensor inputs on the characters with mouse use or keyboard inputs in a single interaction? Or should the two interfaces be kept separate, with complementary but distinct functions?

A test of a mixed interface, using Barney and the mouse together in a simple counting task, provided important guidance. All of the subjects were familiar with Barney from previous tests and all were computer users in their homes, meaning they had extensive experience with both interfaces. When they played with Barney in his freestanding mode at the start of the testing session, they interacted with him directly, attending to him visually, listening to him, and acting on his sensors. When it was time to use him

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with the computer, however, their performance changed dramatically. They sat Barney next to them by the computer, and then immediately stopped interacting with his sensors and grasped the mouse, gazing expectantly at the computer screen and ignoring Barney. When he spoke to them during computer use, they demonstrated an unexpected ability to listen to him while using the mouse at the same time. When Barney commented on their actions with the mouse or gave instructions for pointing and clicking, for example, children kept their eyes onscreen yet responded to him with smiles and comments and, most importantly, by using the mouse as he asked.

When Barney began directing children to use his sensors and the mouse together for software tasks, however, a host of problems emerged. The task was simple in theory: Squeeze Barney's hand to count out a requested number of items (one item for each squeeze) and then use the mouse to click a GO icon when the child judged the set was complete. In practice, however, children's execution was fraught with problems. As expected, children reached for Barney's hand with one hand while keeping the other on the mouse, or even let go of the mouse completely to grasp Barney's hand with the same hand they had been using to control the cursor. The result was that they inadvertently moved the cursor as they reached or when they released the mouse to grasp his sensors, forcing them to have to reposition it on the correct icon again before going on with the activity. They were also easily confused by the sequence of events. When, exactly, were they to use the mouse versus Barney's sensors? What were they to do when they made a mistake and counted too many? In an attempt to coordinate the two interfaces together, some children adopted a strategy of keeping one hand on the mouse and one on Barney. This was an awkward posture that degraded their cursor control, especially when they chose to keep their dominant hand on Barney and their other hand on the mouse. But perhaps the most striking result of the study was a strong transfer of expectations about *content*. Children expected that if they squeezed Barney's foot during software use, for example, he would respond as he did in freestanding toy mode: He would sing a song. This expectation persisted even if Barney had explicitly indicated otherwise in his instructions. In other words, not only did young children find it difficult to coordinate the two interfaces together, but they expected Barney's interface to keep the same functionality it had in one-on-one play. He was not expected to change his

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behavior just because a computer was present. Based on these results, the software and Barney's role in it were deliberately designed to build on children's existing expectations, not only about Barney, but about software use as well.

Barney at the computer

Reconciling the two interfaces required revisiting Barney's social role in relation to the child user. As an authority figure, children expect him to offer guidance and help in their performance, yet they also expect him to still "be Barney," that is, to still do the things he does in free standing play. To keep the integrity of Barney's interactions, his social role at the computer was designed to be similar to that at the television. In other words, he acts not as a direct play partner, but in the less dominant role of coach, or sidekick. And to both maintain simplicity and be consistent with user expectations, his own functions are carefully segregated from computer control. To this end, onscreen activities are supervised and directed not by Barney, but by onscreen characters in the software itself. Everything related to computer control is done with the mouse, and the onscreen characters relay all relevant interface information to the child: where to click, the goal of the task, and so on. Barney's focus of attention is the child's actions. His comments are reactions to the child's performance using the software, making his social role a complementary rather than central one. In keeping with his role as an authority figure, he praises correct responses and offers hints when the child makes errors on structured tasks like shape recognition or counting. If a child selected a square when asked for a triangle, for example, Barney might say "We're looking for a triangle. A triangle has THREE sides. Pick the shape that has three sides!" In addition to this new type of interaction when the child is using the mouse, when his own sensors are actuated Barney remains true to his freestanding performance, but with a new twist. His feet remain an interface for songs, for example, but now the songs are new tunes, written as joint performances shared by both Barney and the onscreen characters together. Barney's eyes remain a dedicated peek-a-boo interface, but now the onscreen characters play along, covering and uncovering their eyes along with Barney and reacting appropriately (saying "Peek-a-boo!" when Barney's eyes are uncovered, for example). Barney's hands remain an

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interface for games as well, but now the games are onscreen. Hand squeezes result in Barney "taking a turn" – coloring a section of the drawing himself, adding his own shape, etc. and reflecting on his actions. If the child has colored a picture all in red, for example, and his hand is squeezed, he might say “Wow! That’s a lot of RED! I’ll color this part red, too!” and a piece of the picture image gets colored red. Just as in his free standing mode, hand squeezes are the interface that cause him to participate with the child during a game.

Arthur and D.W. at the computer

Arthur and D.W.’s social role in relation to the older children who are their users is that of a peer, not an authority figure. The dynamics of peer interactions for this age of child, combined with the increased cognitive sophistication of four to seven year olds, means that Arthur and D.W.’s interactions at the computer will be of a different form than those used by Barney. In terms of peer interaction and older children, the best way to understand Arthur and D.W.’s social role is to contrast it with that of Barney. Barney’s role as authority figure or guide means that he is aggressive in his pedagogical role. When a child makes an error he automatically offered a hint, for example. As peers, Arthur and D.W., in contrast, do not rush to the child’s assistance if an error is made. Like Barney, they react sympathetically and encouragingly, but they do not offer help at once. They will periodically offer to help, saying “Squeeze my ear for a hint!” and if the ear is squeezed, they offer a verbal hint. They also offer assistance saying “Squeeze my hand and I’ll take a turn!” and if the hand is squeezed, they will actually model solving or taking a step toward solving the task the child is working on. But they do not give any assistance until the child acts on one of their sensors, making a conscious choice to seek assistance. Requiring the child to actually choose to get assistance makes Arthur and D.W. more like peers because it makes them appear to respect the child’s own efforts. It is as if the child had said “Don’t tell me, I want to get it myself!” and Arthur and D.W. were respecting their wishes.

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The fact that Arthur and D.W. deliver hints on demand when their ears are squeezed leads to a discussion of the other ways in which Arthur and D.W. differ from Barney in their interactions, based not just on their social roles but on the cognitive sophistication of their target users. Given the younger age of Barney's target users, strict consistency between the functions of his sensors in free standing play and in PC interaction was necessary for ease of use. Not only were they consistent with free standing play, but their functions also never changed when at the PC. Barney's sensors maintain the same functions throughout PC interaction: Feet always give songs, eyes always result in peek-a-boo, hands are for games. Arthur and D.W., however, do not utilize such strict consistency. Just as their own free standing interfaces utilize the same sensor for different functions depending on context, their sensor functions at the PC diverge from what they are used for in free standing play and also change depending on what specific interactions are being engaged in at the PC. The character's interface is still carefully segregated from the PC interface as in Barney's PC interactions. The functions that the sensors do perform, however, are both more context-specific to the particular PC interaction being engaged in and less concretely connected to Arthur and D.W.'s free standing play functions.

In free standing mode, ear squeezes cause Arthur and D.W. to say phrases that let you hear what they are 'thinking.' At the PC, ear squeezes result in hints, which can be thought of as a special case of what the characters are 'thinking,' (in this case what they are thinking while watching the child play a game on the PC). For example, if the child is trying to select the onscreen character who has correctly spelled the word CAT, Arthur might say "Cat is spelled C..A..T…Pick the person who spelled it that way!" The watch sensor, similarly, retains a time function, but one that is augmented by the graphical capabilities of the computer. Squeeze the watch during free standing play and the characters say the time. Squeeze it when they are interacting with the PC and they not only tell you the time, but an onscreen clock appears that displays the time using both analog and digital clock forms. The hands and feet perform functions very different from their free-standing ones, however. The hands have no specific function in free standing play, but serve to repeat phrases or augment game play, depending on the interaction the child is engaged in. At the PC, however, hand squeezes cause the characters to "take a turn" and participate in the onscreen

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activity. The characters not only take a turn, but they “think out loud” about what they are doing in the same way Barney might. For example, if the child is selecting the correct spelling for a given word from among several options presented by onscreen characters and squeezes a hand sensor, Arthur and D.W. say “Hm. Cat is spelled C-A-T. I’ll pick Muffy!” The computer then executes the next step in the game as if the character had clicked on Muffy. The feet also have a different function during PC interaction. Instead of playing specific games as they do in free standing play, squeezing the feet sensors at the PC results in social word play in the form of knock-knock jokes. The character asks “Hey, how about a knock-knock joke!” and the onscreen character responds, saying “OK! Knock knock!” The character then says “Who’s there?” and the onscreen character delivers the set up line (“Dwayne!”, for example). When the character says “Dwayne who?” the onscreen character says “Dwayne the bathtub, I’m dwowning!” and the characters, both onscreen and off, laugh. The effects of the knock-knock jokes were striking. Children laughed along or groaned at the jokes, and then spontaneously began telling their own knock-knock jokes to others in the room with them. The social nature of shared joking modeled by Arthur and D.W. prompted children to initiate that same social behavior with others.

The use of different functions for the character sensors at the PC than are used in free standing play is possible because Arthur and D.W.’s target users are cognitively more advanced than the young children and infants who are the target audience for Barney and the Teletubbies. Their working memories are larger, allowing them to remember the various functions of the different sensors in the different usage scenarios (Case, 1985). Our testing with these older children revealed that they were not confused by changing functions across different usage contexts (free standing vs. PC), and adapted easily to them. The Arthur and D.W. software takes this result one step further by not only changing functions at the PC relative to free standing play, but by changing functions within the software as well. Each CD-ROM has a special “dance theatre” activity in which the child teaches an onscreen version of the interface character to dance by squeezing the character’s hands, feet, and ears. Each sensor results in a different dance step, and the steps can be combined to execute unique dances by ordering the steps in different ways. The watch sensor executes the dance. The mouse is used only to select backgrounds and musical themes to dance to.

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Testing with children found that they easily changed their expectations about the character's sensors as they moved from the software games to dance theatre and back again, confirming that this older age group is able to accommodate diverse interface functions in a way that younger children could not. By building interfaces that match the sophistication of these older users, interface characters capitalize on user competence to deliver a wider variety of interactions to children. By keeping these interactions social (child inputs result in taking turns, offering hints, teaching someone to dance, etc.) they also capitalize on the social expectations that are the basis of the pretend playmate interface itself.

Whither the future?

Physical interface characters use rules of social behavior as the basis for the form and content of their playful learning interactions. The nature of the social interactions and the complexity of the functionality required for each character are shaped by both the personalities of the interface characters themselves and by the social and cognitive abilities of the target users for each product. While each character is self-contained with fixed content, a wireless radio link allows the character to receive new speech and new behavior patterns in conjunction with other media, such as the TV or PC. The wireless link makes the character's interaction with these other media invisible and intuitive, just as it is with social actors such as peers or parents. The character's mimicry of social behavior with these other media is appropriate to the medium in question, and extends the social interface in such a way as to augment these other media using social interactions in the same manner that they would be augmented by another person. What are the next steps in the evolution of physical character interfaces? What more can such technologies do? A good way to peer into the future is to examine the limitations of the current design, and to ask what can be added to make the interface characters both more lifelike and better learning partners.

<u>The social value of memory and change</u>

One limitation of the current design of character interfaces is that they have no memory of their own previous interactions, and their responses to the child are generic in nature. This is not socially

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appropriate. One of the ways playmates create a feeling of intimacy with one another is through the use of personalized information. Character interfaces would seem much more lifelike and aware of the user, and thus more engaging, if they were able to respond to the user in peronsalized ways. There are simple and superficial ways to do this, of course. Arthur and D.W., for example, can know the child's birthday and remember when the child wakes up in the morning, using their calendar and clock functions. Another superficial way to create intimacy is through identification. It is possible to enter and save a child's name into the pretend playmate character, for example, so the child can be queried by name during interactions.

A far more subtle and powerful strategy, however, would be to have the character recall not just the child's name or other isolated data, but also recall specific events and activities the child has engaged in with the character. Reminders of such shared experiences can make the pretend playmate seem aware of its own previous experiences and aware of the personal context it shares with the child. The character could spontaneously recall the themes or events from a television program viewed by the child with the character, and ask questions or make comments about them. The shared reference would make the character seem more intelligent. Even more effective would be specific recollections by the character of the child's actions in previous activities. The character might remember a particularly difficult problem the child solved, and say proudly "Remember that number puzzle you solved yesterday? You are good at that!" Such interactions not only enhance the character's social sophistication, but they also act as important reminders of competence for the child, and help build self esteem.

Another limitation of the current design is the fixed nature of the character's interactions. Human play partners are dynamic. They always bring new and different ideas and activities to their social interactions, and their social play interactions are endlessly variable and spontaneous as a result. Character interfaces would both seem more lifelike and give children richer, more diverse experiences if they could "pick up" new games, phrases, and other content over time. In theory, the character can even track children's usage patterns. This would let the character drop unpopular games and add new ones over time

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for example, or even increase the difficulty of problems within games as children demonstrate mastery in their interactions.

A practical question is how such information will be exchanged between the character and the information source. As with the real-time PC and TV interaction of the current characters, a wireless link is clearly superior to any others because it does not impose artificial restrictions on the child's social engagement with the interface character. The social implications of the character storing or sending information go beyond just the concrete question of how the information is physically transferred, however. What does the character do during the information exchange? Current designs, such as Mattel Interactive's My Interactive Pooh, have the character becoming unresponsive and inactive. Such a response is socially inappropriate. If a human peer were to suddenly became inactive and unresponsiveness, even with a warning, it would be alarming and unnatural. A far better design would be one that let the character continue to interact with the child while exchanging additional information "in the background." Like the wireless connection itself, such a design would make the background data transfer invisible to the user. Such invisibility is key to preserving the character's lifelike pretense, which forms the basis of the pretend playmate interface itself.

Conclusion

Character interfaces are a form of puppetry. As physical characters who resemble and sound like familiar characters from television, they "stand in" for their television counterparts, evoking the same responses from users that social interaction with the television characters themselves would. The illusion of the interface character's authenticity extends beyond appearances and into the realm of behavior. The character's social interactions with the child must conform to the child's implicit social expectations, not just in terms of the character's personality but in terms of the social rules that govern the social exchanges in any specific social context. Puppeteers, as actors, bring their characters to life in this way, using a form of pretend. They rely on their own social skills, and their ability to mimic different personalities and voices, to cause their puppets to respond and act as if they are the characters they represent. Character

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interfaces utilize the same pretend strategy to invoke the same sorts of responses from users. The only difference is that they use digital technologies, rather than human actors, to make the interface characters move and speak.

Embodying an interface in a physical character allows users to respond to the interface with the social skills they already possess simply by dint of being human beings. Designing the interface to match these skills, and the expectations they create, makes interaction simple and intuitive for the user. Succeeding with such designs requires balancing the personality of the interface character with the abilities of the target users. As the existing examples demonstrate, this requires careful testing and evaluation – particularly when the users are children, whose competencies and expectations about social interaction are different from those of adults. Using such characters as interfaces makes technology less cold and abstract, and more concrete and emotionally engaging. As technology continues to increase in power and sophistication, the capabilities of social interfaces such as pretend playmate characters will grow as well. While not suitable for all applications, they offer a new and powerful alternative to the standard point-and-click or other impersonal interfaces currently in widespread use. Their simplicity, building on the social skills all users have, makes them a very attractive design for consumer applications, particularly when the users are children or other users who require a human touch in their experience with technology.

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Figure 1. Technology without personality. The “chassis” for the Barney interactive character, with hand, feet, and eye sensors attached.

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Figure 2. Interactive Barney character, “in the skin.” Motors in the ‘shoulders’ and ‘neck’ let the character move and gesture while speaking. Children interact with Barney by squeezing sensors in the hands and feet, and covering a light sensor in his eye.

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Figure 3. Interactive Teletubbies characters. Children interact with them by squeezing sensors in the hands and feet, and pressing the tummy screen.

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Figure 4. Interactive Arthur and D.W. characters. Children interact with the characters by squeezing sensors located in the hands, feet, ears, and watch (visible on right arm).

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