

# When the Interface is a Talking Dinosaur: Learning Across Media with ActiMates Barney

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## ABSTRACT

ActiMates™ Barney™ represents a new form of interactive learning product for two- to five-year old children: a small computer that looks like an animated plush doll. He can be used as a freestanding toy and, by means of a wireless radio link, he can interact with PC-based software and linear videotapes. In each mode, Barney takes advantage of children's social expectations about playmate performance to engage the user in learning interactions. The theory and practice behind Barney's performance in each mode (freestanding, with the computer, and with the television) are described, as well as how key research results shaped the interface across the different modes.

**KEYWORDS:** learning, interface, children, interactive media

## INTRODUCTION

### A theory of interactive learning

Recent theory and research in children's learning has emphasized the importance of social interaction as a mechanism for mental growth [18,23,24]. A key learning process identified by this school of thought is a type of social intervention called *scaffolding*. Scaffolding is the process whereby an adult or more mature peer supports a child's acquisition of a new skill by providing assistance at key points during the execution of the skill itself, in a form of collaborative effort. An example of scaffolding might be helping a child learn to count by filling in numbers in the count sequence when the child is unable to remember them, or manually guiding the child's finger to each object being counted while counting along, to structure the task as it is executed. The metaphor of the scaffold is meant to capture the temporary and transitional nature of the learning intervention. Just as a scaffold is gradually removed from a new building as it is completed and can stand on its own, support of the child is gradually reduced as repeated effort leads to mastery of the new skill.

A critical part of scaffolding as a learning intervention is the use of language. Language in this framework gives form to thought by guiding and directing mental processes. Young children are thought to acquire concepts and abilities by gradually internalizing the verbal support and direction of others, until they become capable of guiding their own behavior using the same skills and strategies that were initially provided externally [4].

### Applying scaffolding theory to educational technologies for children

Scaffolding theory holds great promise for educational technologies, because of the strong parallels between the nature of the user interface and the nature of scaffolded learning. Learners control the pace and course of action in scaffolded learning efforts, just as they do in their use of interactive technologies. And scaffolding requires context-specific responses to repeated efforts over time, something that computers can provide very well. The key limitation in translating this model of learning into technology use has always been its fundamentally social nature, and its heavy reliance on language. Most computer interfaces are strictly visual, relying on a small screen with two-dimensional images controlled by some form of pointing device – a form of interaction that is hardly social. Even when a small, talking character is included in the graphical interface itself, the abstract nature of the interface often fails to evoke the basic social expectations of cooperation and verbal engagement that make scaffolding possible.

ActiMates Barney (hereafter simply A/Barney) represents a unique interface that uses the social dynamics of pretend play to integrate technology and learning. By virtue of being an animated plush doll who resembles and behaves like a familiar media character, A/Barney taps into powerful pretend play and toy experiences common to early childhood. Young children 'animate' dolls and other objects on their own, treating them as if they are sentient and responding to them in ways that mimic familiar social interactions (comforting a 'crying' doll is a classic example) [1]. Using speech and movement, A/Barney invokes similar pretend responses as an interface strategy. While there have been other attempts to use a concrete character as an interface for young children's interactive

learning [5,6], A/Barney is the first to rely so heavily on language and social interaction in its design.

The goal of A/Barney's design was to use the social mimicry of pretend play, combined with the differential responsiveness of interactive technologies, to provide scaffolded learning experiences for young children, both during toy play and in combination with other learning media. The remainder of this article describes the application of scaffolding theory to the content and design of each of A/Barney's modes of interaction, and the iterative design and research process that shaped the feature set included in the final product.

### **THEORY INTO PRACTICE: ONE DINOSAUR, THREE WAYS**

The core interface across all three of A/Barney's modes is A/Barney himself. A/Barney is a 13" animated plush doll. Motors provide simple arm and head movement, and a small loudspeaker provides audible speech. A/Barney's interface is a set of five sensors: Four touch sensors (one in each hand and foot), and a light sensor located in his left eye. A ROM chip hidden in his body allows him to respond to children's inputs by moving and speaking using pre-recorded, digitized speech and programmed motion. A/Barney interacts with other media using an internal radio transceiver similar to that of a walkie-talkie. When a special transmitter is attached to a TV and VCR, he can receive new speech and motion from encoded videotapes that play as the child is watching the video. When a transmitter is attached to a PC running encoded CD-ROMs, A/Barney both receives and transmits data. He both receives new speech and motion content from the computer and transmits inputs from his own sensors back to the computer, as well. In this way, A/Barney not only reacts to children's actions as they use software with a conventional pointing device such as a mouse, but children's actions on his sensors also affect what happens in the software.

The task of creating an integrated model for A/Barney's performance as a pretend playmate who could be integrated into a variety of electronic media interactions presented a novel design challenge. It required defining a set of conventions for interacting with A/Barney that were both consistent across all modes of use *and* flexible enough to accommodate the context-specific variations each type of interaction required. Consistency was created by building the interface conventions around the one element that remained constant across all modes of use: A/Barney himself. In practice, this meant that even though A/Barney's freestanding toy mode performance differed from that in the other modes in important ways, it was this mode that set the standard for his performance when watching television or playing at the computer.

#### **A/Barney as a freestanding toy**

The research conducted on A/Barney during the development of his freestanding toy mode generated the

design principles that guided the development of his other modes. These principles can be summarized as three simple maxims.

#### *Playmates should be directive, but friendly*

In freestanding toy mode, A/Barney is assumed to be the child's sole playmate, and his interactions are designed to promote the child's direct engagement by being conversational and familiar. He refers to the child using the pronoun "you," and to their joint activities using the shared pronoun "we." Research on adults using phone interfaces and on speech in the software interface has found that direct queries (for example, "What would you like to play?") prompt user responses less often than do explicit directives [16,21]. Building on these findings, A/Barney does not ask questions as part of his verbal interface. Instead, he makes simple directive statements such as: "Cover my eyes to play Peek-a-boo!" "Squeeze my middle toe to sing a song!"

Testing of A/Barney's games and activities demonstrated that the use of concrete directives was an effective interface strategy, but also revealed that it had a significant drawback in the social context of a two-person play dyad: over time, the directives had the unintentional effect of making A/Barney seem bossy and task-driven. It often seemed that every statement he made was an instruction, particularly when no game or song was active, and he was prompting the child to select an activity. This constant browbeating quickly reduced children's interest during free play use. To remedy this situation, A/Barney's interface instructions were intermingled with a set of compliments and positive other-directed statements having no functional value, such as "This is fun!" "I like playing with you!" "You're my special friend!", and so on. Adding these phrases to the interface made A/Barney seem much less task-oriented, and as forms of unconditional praise, they bolstered children's pleasure during interactions as well.

#### *To each sensor, it's own function*

Early testing of the doll's sensor interface with young children clearly demonstrated two critical facts. First, children easily understood that acting on A/Barney's body parts (eyes, hands, and feet) initiated interactions. They responded immediately to requests such as "Squeeze my hand to play a game!" for example, by reaching for A/Barney's hand and squeezing it, then waiting expectantly for him to speak. However, children of this age were consistently unable to use A/Barney's sensors in any combinations, simultaneous or sequential, as part of an interface. That is, children could not be asked to squeeze both a hand and foot sensor together to start a game, nor could they be asked to first cover A/Barney's eye and then squeeze his hand in a two-step sequence. These results led to a highly simplified design, whereby each class of body part (feet, hands, and eyes) is dedicated to one and only one class of response. Given children's inability to reliably identify left and right at this age [12], left and right were not differentiated in the interface – both hands, both feet,

and both eyes are treated redundantly.) There are three types of interaction:

A/Barney's feet are dedicated to songs. Squeezing the touch sensors in either of A/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.*)

A/Barney's hands are dedicated to activities and games. Squeezing the sensors in either of A/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.

A/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 A/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" comment, when A/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 by their location on his body was assessed by having children return repeatedly to play with A/Barney over several months, for different studies. When children returned, they were asked to make A/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.

#### *Everything interrupts everything else*

A key element of play is the intrinsic motivation derived from its self-directed form [17]. Similarly, in social pretend play children experience a feeling of control as the participants jointly create play events [7]. How could A/Barney mimic this responsivity? The answer came from studying two key elements of children's patterns of interaction with A/Barney: their deliberate disruption of ongoing interactions, and their conscious searching for favorite songs or games as part of their play.

Children's typical performance during play sessions was to squeeze A/Barney's hand or foot, and then play or sing along with whatever activity or song A/Barney produced. Since he randomly varied the items in his hand and foot menus and moved through all items before repeating any, the selections were always different with each round of use. This variety of presentation kept children's interest high. However, during many play sessions, particularly after children had become familiar with A/Barney's offerings, they frequently did something striking: they started a given song or game, only to then deliberately try to terminate it

by acting on a different sensor. In A/Barney's early designs, such user-initiated interruptions were not part of the interface. Interruptions were viewed as accidents to be avoided, so once a song or game was started, it had to be completed before a new activity could be selected. But the research clearly documented children purposefully trying to stop a song by starting a game, for example, or trying to stop a game they themselves had started in order to play peek-a-boo, and so on. Even within the game of peek-a-boo, a similar play pattern was observed. Children would cover A/Barney's eyes, and then uncover them while he was still speaking, to stop his speech mid-utterance.

In addition to the deliberate interruptions, another pattern of interaction was for children to try to force A/Barney to play one specific game or song they desired, by trying to squeeze the same sensor repeatedly. Children spontaneously squeezed his toe several times in a row to find a specific song, for example, in efforts that mimicked cycling through the tracks on an audio CD. They showed a similar preference for finding particular games. As with cross-sensor interruptions, A/Barney's early interfaces did not support this form of searching, and children's reactions to their limited choices were very consistent: diminished interest. Their attention wandered as they waited for unwanted songs or games to end; several children actually became aggressive with A/Barney as well.

The lesson was obvious. Interruptive functions had not been included in the design because it had been assumed children would 'play along' with A/Barney. Instead, children expected the opposite: A/Barney was supposed to play along with *them*. Subsequently, all of A/Barney's interfaces were changed such that (1) any action on any sensor caused A/Barney to change what he was doing to the function associated with the triggered sensor; and (2) repeated inputs on a single sensor cycled the content of that sensor's menu. These changes increased A/Barney's responsiveness to child action, and subsequent testing showed that it increased the length and tempo of children's play with him. It also introduced a new risk: unintentional interruptions. This was especially true of the light sensor, since it responds to changes in light level – something not always due to user action. The new risk was judged acceptable, however, because of the overall enhancement A/Barney's responsiveness brought to the quality and tone of children's interactions with him.

#### **A/Barney at the computer**

A/Barney's interactions with the computer provided a striking opportunity to expand his repertoire of functions. Once the PC transmitter establishes the two-way radio link with A/Barney, all of his intelligence becomes a subset of the computer's processing power, and his internal functionality is suppressed. At the PC, therefore, his intelligence is limited only by the power of the PC itself. New speech can be transmitted to him as needed from specially designed software, and his sensors can be

assigned entirely new functions as well – even combined with keyboard or mouse inputs, to allow for a variety of different interactions.

The content of A/Barney's interactions at the computer was shaped by reviewing the literature on cooperative learning methods used with computers in formal instruction in schools [10,13,14,20]. Cooperative learning, like scaffolding theory, stresses the social context and verbal interaction among learners. 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 learning partners, especially thinking aloud during task execution, praise, and hints, which are most effective in promoting learning and mastery. The cooperative learning literature did not, however, provide insight into how A/Barney, as a simulacrum with his own interface, should be integrated with the computer. Was it possible to create interfaces that combined A/Barney's sensors with mouse use and integrated him closely with software content?

An initial test of a mixed interface, using A/Barney and the mouse together in a simple counting task, provided important guidance. All of the subjects were familiar with A/Barney from previous tests, and all were computer users in their homes. When they played with A/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 with the computer, however, their performance was markedly different. They sat A/Barney next to them by the computer, and then immediately stopped interacting with his sensors and grasped the mouse, while gazing expectantly at the computer screen. When he spoke to them, they demonstrated an unexpected ability to listen to him while using the mouse at the same time. When A/Barney commented on their actions with the mouse, or gave instructions for pointing and clicking, children kept their eyes onscreen, yet responded to him with smiles and comments, and most importantly, by using the mouse as he asked.

When he asked children to use both his sensors and the mouse together for software tasks, however, a host of problems emerged. Children would inadvertently move the cursor when they released the mouse to grasp his sensors, forcing them to have to recover its location before going on with the activity. They were easily confused by the sequence of events, as well. When, exactly, were they to use the mouse versus A/Barney's sensors? In an attempt to coordinate the two interfaces, some children adopted a strategy of keeping one hand on the mouse and one on A/Barney, an awkward posture that degraded their cursor control, especially when they chose to keep their dominant hand on A/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 A/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 A/Barney had explicitly indicated otherwise in his comments. In other words, children did not expect A/Barney to change his behavior just because a computer was present.

Based on these results, the software and A/Barney's role in it were deliberately designed to build on children's existing expectations, not only about A/Barney, but about software use as well. Subsequent testing refined the elements of this design, producing a media-specific extension of the original principles created for freestanding toy mode.

#### *From playmate to coach*

The social dynamics of shared computer use differ from those of shared play. In shared play, the play partner is the focus of attention. In shared computer use, both partners focus their attention on the computer instead. Since A/Barney's goal is to stimulate the child's learning while using the computer, *his reactions and comments are all about the child's performance using the computer*. Unlike freestanding toy mode, in computer mode he never attempts to draw the child into playing with him, except during long periods of mouse inactivity. When the child is using the mouse interface, A/Barney responds to the child's actions in several specific ways, all primarily verbal, that mimic those that research indicates are used by effective learning partners:

Giving content hints – If the child is asked to select a triangle from a set of shapes and makes an error, for example, A/Barney provides additional information, such as the fact that triangles have three sides.

Praising performance – A/Barney congratulates the child whenever a right answer is selected, regardless of number of errors or time on task. He also makes task-specific compliments, such as “You have a good memory!” on memory tasks, “You sure know your letters!” on letter tasks, and so on.

Modeling performance – When A/Barney takes his turn during open-ended tasks, he models the cognitive and interface performance children can use. On a coloring task, for example, he might say, “I think I'll color this part yellow!” and change a section of the drawing.

Articulating patterns – During open-ended activities, A/Barney recognizes simple logical and sequential patterns in the child's performance and identifies them verbally. If a child has used all the same color during a coloring activity, for example, A/Barney comments on that fact. If the child squeezes A/Barney's hand after the comment, he will take a turn and continue the child's pattern, while

verbally reinforcing it: “You used a lot of red. I’ll color this part red, too!”

#### *To each interface its own function*

To keep the integrity of A/Barney’s interactions, his role at the computer was transformed from that of direct play partner to the less-dominant role of coach, or sidekick. His own functions are carefully segregated from computer control. To this end, although A/Barney reacts to the child’s performance, the onscreen activities are supervised and directed not by A/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. A/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 A/Barney and the onscreen characters together. A/Barney’s eyes remain a dedicated peek-a-boo interface, but now the onscreen characters play along, covering and uncovering their eyes along with A/Barney and reacting appropriately (saying “Peek-a-boo!” when A/Barney’s eyes are uncovered, for example). A/Barney’s hands remain an interface for games, but now the games are onscreen in the software in the form of simple, linear vignettes. During structured tasks like drill activities, hand squeezes result in brief onscreen lessons related to the game content that are executed in squeeze-by-squeeze fashion, just like freestanding mode games. During open-ended activities like drawing or building collages with shapes, hand squeezes result in A/Barney “taking a turn” – coloring a section of the drawing himself, or adding his own shape, and reflecting on his action.

#### *Everything interrupts everything else redux*

Subsequent testing with young children demonstrated that their interactions with A/Barney and the software were highly similar to their interactions with A/Barney alone in one key respect: they showed a strong tendency to ‘graze’ across the different functions available to them. They might, for example, use the mouse to solve a problem, then squeeze a toe to sing along with a song, then play peek-a-boo, and then use the mouse again. As in their freestanding play performance, deliberate interruptions were common. To accommodate this pattern of performance, all of A/Barney’s interactions were designed to be modular and mutually exclusive. The mouse was integrated into the universal-interruptibility design established in freestanding mode, and followed the same rules. Just as with the other sensors, a mouse click terminated any ongoing interactions and started the next event associated with the object the child clicked on.

#### **A/Barney with the television**

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 [3,8,9]. This form of interaction, described as ‘co-viewing,’ is almost completely verbal. In TV mode, A/Barney performs this function through the use of specially encoded videotapes and a transmitter attached to a VCR. Unlike PC mode, however, A/Barney’s comments on video content are fixed. Being part of the tape, the comments are the same each time the tape plays, and the child’s actions on A/Barney cannot affect what happens on the tape or what A/Barney says about it.

#### *From playmate to co-viewer: Less is more*

Similar to PC mode, A/Barney’s performance in TV mode is not the dominant role of playmate, but the less-engaged role of viewing partner. A/Barney and the child again share a common focus of attention, but this time it is the television. Children typically sat or lay with A/Barney while watching the television. Since A/Barney’s goal in this mode is to promote comprehension of video content, his comments are like those in PC mode: his speech is directed to the child, but he is reacting to what is happening on the screen. He never draws attention to himself or his functions. He promotes comprehension by scaffolding TV viewing in a variety of ways:

Directing attention – A/Barney says things such as “Watch this!” or “Oh, look!” when important events are shown onscreen.

Modeling involvement – A/Barney reacts to onscreen content with appropriate responses such as surprise (“Oh, my!”), and emotional responses to events (cheering at good news, expressing concern when hearing bad news, and so on). He also sings along with songs, counts along with onscreen characters, and recites the alphabet with them.

Querying the child – A/Barney asks questions about events onscreen that are designed to promote children’s thought, such as predictions (“What do you think will happen next?”), requests for identification (“What’s that?” “Who’s that?”), and preference queries (such as “Would you like to do that?”).

Using vocabulary words – A/Barney labels objects onscreen such as letters and numbers, and identifies the colors or names of specific objects, as appropriate.

Encouraging physical participation – A key element of preschool learning is musical engagement and physical activity. During musical events onscreen, A/Barney sings along with songs and explicitly encourages the child to imitate the dancing of onscreen characters, saying “Spin all around!” or “Wave your arms!” as songs are underway.

Research with children watching a program while A/Barney delivered these comments demonstrated that they were highly effective. Similar to their performance during computer use, children showed an ability to divide their

attention, listening to A/Barney's spoken comments *and* watching onscreen events at the same time. Several children responded verbally to A/Barney's questions, or repeated his comments to others watching along with them during the testing session. Even when children did not show an overt response, their eye movements revealed that they were listening to A/Barney and processing his comments as they kept their eyes onscreen.

The research also revealed that the frequency and timing of co-viewer comments was a critical design element. Educational programming for young children is designed to maintain attention by being fast-paced and full of sights, sounds, and action. Fitting A/Barney's observations into such content without his talking over onscreen events was difficult to accomplish. Testing clearly indicated that too many comments distracted children by competing with action on the screen. A low frequency of comments was best; A/Barney's individual prompts were novel enough to catch children's attention but not so frequent as to be disruptive. In terms of timing, the most significant discovery was the need to allow children plenty of time to react to what A/Barney said. Attention directives, for example, needed to happen before, not during, the events they were targeting. A comment that was synchronous with the event it was targeting was ineffective because children's latency to focus their attention was too long, and the event would end too quickly to be processed.

#### *Sensor functions should fit the social context*

TV mode raised a troubling design issue for A/Barney: what was the appropriate role for his freestanding functions, such as songs? In PC mode, these functions were preserved and augmented by keeping them intact and integrating them into the software content itself. This design had the virtue of both keeping A/Barney's interface consistent and at the same time keeping the child's attention focused on the computer screen, even if his songs and games were not a part of the actual computer task. The linear nature of video content precluded this design from the start. A song on demand during TV viewing could not be integrated into what was on the screen; it would be a distraction, creating exactly the opposite of what was intended in the co-viewing educational model.

One possible solution was to simply deactivate A/Barney's sensors during TV viewing. This meant he would comment on what he was watching, but would not respond to child action. Testing of this scenario, however, showed it was inadequate. Children acted on A/Barney's sensors far less often than during freestanding play or PC play, but when he failed to respond they were perplexed. Why was A/Barney talking, yet not responding to their actions? His lack of responsiveness actually became a distraction in itself, as children turned their attention to A/Barney and tried to elicit a response from him and began ignoring the content of the program they were viewing.

The key to the correct design came from a careful review of how, exactly, children engaged not only A/Barney, but also their parents, during tests of TV mode. Unlike their interactions with A/Barney in freestanding mode or PC mode, children did not give their full attention to A/Barney when they interacted with him in TV mode. Rather, they tended to reach over and act on A/Barney absently, as a secondary behavior during viewing. What was striking was that they tended to act on their parents in the same way, *often with an identical action*. If they patted their parent's arm while viewing, for example, they also patted A/Barney. The parent's response, typically a brief recognitory action (a return pat, a stroke, etc.), typically satisfied children. Would they be satisfied with a similar, abbreviated response from A/Barney?

Subsequent testing revealed that this was in fact the case. If the children squeezed A/Barney's hand or foot, 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 A/Barney did not play games or sing while watching TV if his hands or feet were squeezed. Peek-a-boo, however, was a different story. Although it was played more laconically, children still expected that A/Barney would respond to having his eyes covered – especially during an activity that depended on being able to see. In the TV viewing context, in fact, covering A/Barney's eyes seemed to be a sort of teasing behavior that children enacted with a mischievous grin, as if they were deliberately obstructing his view. To accommodate this specific interaction, peek-a-boo was kept fully functional in TV mode, and TV-specific comments such as "I can't see the TV!" were added to A/Barney's repertoire – changes that satisfied children in subsequent tests.

#### *Interruption and the limits of pretend*

TV mode differs from A/Barney's other modes in one important way. Unlike freestanding toy mode and PC mode, where children's own actions are the focus of A/Barney's attention, in TV mode A/Barney is reacting to the content of the program being viewed. Yet for him to be responsive to children, and be consistent with his behavior in other modes, all child-initiated actions still take precedence over his reactions to the TV program, and interrupt them. Squeezing a foot or hand causes him to interrupt his TV comments and give one of special recognitory phrases, and covering his eyes makes him play Peek-a-boo.

Peek-a-boo presents an unusual case, however. In his other modes, keeping A/Barney's eyes covered for a long period of time leads to a termination of peek-a-boo. In freestanding play, A/Barney stops making comments about not being able to see and prompts the child to play a game or sing a song. In PC mode, the end of peek-a-boo results in either the same reaction from A/Barney or a request for

mouse action from the onscreen character. Auto-termination of the game makes sense in these modes, because there is no expectation that A/Barney needs to be able to "see" to play his games or sing songs. In TV viewing, however, A/Barney's being able to "see" was a key element of the pretend engagement and ending peek-a-boo automatically raised difficult issues. If A/Barney were put under a blanket and left there, for example, should he terminate peek-a-boo and start talking about what was on the television, even though his vision would still be obstructed? Should peek-a-boo be different during TV viewing, and never terminate until A/Barney's eyes are uncovered, to maintain the pretend illusion of his having vision?

The decision was made that the dangers of maintaining the pretend illusion outweighed the benefits in this scenario. A/Barney's performance in TV mode needed to be consistent with his pretend-based design, but to keep it consistent on this point created unacceptable risks. To take just one possible situation, if A/Barney's light sensor became disabled and peek-a-boo did not auto-terminate, he would never be able to interact with the TV at all. Poor lighting conditions could also prevent him from interacting with the TV, even with the sensor intact. Being consistent across modes and auto-terminating peek-a-boo, even though it violated the logic of pretend in TV mode, was judged an acceptable trade-off in light of the possibility that all of his TV interactions would be put at risk otherwise.

## CONCLUSIONS

### Consistency and context in interface design

Shaping A/Barney's interactions to provide educational content appropriate to each mode while maintaining consistency in his interface proved to be the biggest design challenge facing this product. Consistency is critical to a good interface, because it makes interaction predictable and reliable, resulting in less demand on user working memory and less effort spent on learning the rules of task execution [2,19]. Yet the demand characteristics of each of A/Barney's learning modes required that some context-specific changes in the interface be made, if the learning objectives appropriate to each interaction were to be met. The issues associated with altering A/Barney's interface to fit changes in his functions can be considered as a modern variant of the classic "mode" problem faced in early text-editor design [11,15]. In the era before graphical interfaces, the design challenge was that a change in software mode (from editing lines of code to running the program, for example) often meant a change in the functions of a single interface. The F1 key, for example, might mean "cut" in editing mode but then mean "abort" in run mode. The arbitrary nature of the function changes, and the lack of visual feedback that the mode had changed, created confusion among users and led to high rates of error.

For A/Barney, the challenge was similar: functional changes in A/Barney's role meant changes in his interface

that would be invisible to the child user. A/Barney's interface design avoids making these changes confusing because he can do what software interfaces cannot: make the changes fit the demands of the social context in which he and the child are participating, so that they seem obvious and natural instead of arbitrary and artificial. Accomplishing this goal required not only a careful analysis of existing research on learning in social contexts, but also extensive study of young children's interactions with A/Barney himself.

### The pretend playmate as an interface convention

ActiMates Barney is able to scaffold children's learning across three distinct social contexts because his performance in each context matches their expectations of the social dynamics of each interaction. As a freestanding toy, he interacts directly with the child; as a TV co-viewer, he watches along and attends to the television; and as a learning partner at the computer, he offers assistance, encouragement, and observation. These forms of engagement would not succeed unless children were willing to "play along" with the idea that Barney is a social being, and that his behavior should be consistent with the friendly, supportive, and wiser play partner he portrays on his television program.

It would also not have succeeded if children's expectations about social interactions, both one-on-one and with electronic media, were not so clearly differentiated. Indeed, perhaps the most striking aspect of the research and design on this product is the finding of just how elaborate and detailed children's patterns of engagement with different media are, even at three years of age. Barney's interface in each mode had to be carefully refined to match children's existing social repertoires for each – repertoires that were divergent in surprisingly subtle ways. By mimicking the performance children expect from a play partner across different social contexts and in the company of different media, A/Barney is able to maintain an integrity of purpose and interface even as his specific functions and interactions vary.

ActiMates Barney succeeds as a learning product by conforming to the demands of the situation and to the expectations of his users, just as an intelligent, respectful play partner should. And in this way he suggests an important lesson for future interface designs, especially those based on social conventions. Whether it is an intelligent agent who shops for you, or one that tutors you as you learn, technology interaction is a form of consensual play-acting where both the user and the technology have specific roles to play. Such shared pretend is a form of true partnership and collaboration, and achieving that level of user engagement is the ultimate goal of interface design. It seems particularly fitting that a product designed for our youngest users, for whom pretend play itself is a way of learning about the world, should remind us of this simple fact.

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**Strommen, E. F. (1998). When the interface is a talking dinosaur: Learning across media with ActiMates Barney, in Proceedings of ACM CHI'98 (April 18-23, 1998, Los Angeles, CA) Conference on Human Factors in Computing Systems, (ACM/SIGCHI, New York), 288-295.**