The Robotic Preschool of the Future: New Technologies for Learning and Play

Walter Dan Stiehl, Angela Chang, Ryan Wistort, and Cynthia Breazeal
MIT Media Lab
20 Ames St, E15-468
Cambridge, MA 02139 USA
+1 617 452 5605
wdstiehl@mit.edu,

ABSTRACT
Technology can add elements of magic to play and learning and improve communication between students in and out of the classroom. Robots, as a powerful, multi-modal, embodied technology pose a unique benefit to enhancing collaborative play and storytelling. In this paper we present three technologies currently in development in the Personal Robots Group at the MIT Media Lab and describe scenarios in which these systems can be combined to enhance the preschool experience.

Keywords
Robotic companion, pre-school, education

INTRODUCTION
Fantasy play and storytelling have been shown to be vitally important to learning, especially in young children [1]. Technology, if done properly, can enhance the preschooler's play experience, contribute to their storytelling, and allow for children, teachers, and family members to communicate better with one another even at great distances. Robots, due to their embodiment, allow for creative and fantasy based play to enter the real world. Unlike a virtual character which resides only on a screen, a robot can be held in a child's arms or touched and thus provides a very visceral experience.

In this paper we present three different technologies being created at the MIT Media Lab in the Personal Robots Group. Our vision is that each of these technologies holds a unique potential benefit for education and when combined together the resulting experience combines the importance of fantasy creative play and storytelling with important educational benefits. Our vision follows the statement of Arthur C. Clarke that "Any sufficiently advanced technology is indistinguishable from magic" [2]. By introducing appropriate technology we believe we can enhance the magic of play.

BACKGROUND
Unfortunately, in many of today's educational reading toys the child is simply a passive listener and not an active participant. Such systems lack the ability to sense if the child does not pay attention and there is no feedback to the device to encourage the child's active participation.

Recently, robotic devices, such as Lego Mindstorms, have been created based upon Papert's Constructionism idea. While these systems have been shown to be beneficial to young children [3], the form factor of blocks lends itself more to vehicles than soft characters. Additionally, the focus of the interaction is more to teach the foundations of programming to accomplish a task as opposed to free form storytelling.

Today, one focus is to explore how more sophisticated robotic systems could be used in educational settings [4]. While there is much potential for such systems, the current focus on a purely autonomous robot has many technical limitations, especially when the users are young children. A semi-autonomous robot, i.e. a robot with layers of autonomy on top of human control, may be the best solution to keep up with the spontaneity of the child.

ROBOTIC TECHNOLOGIES FOR EDUCATION
In this section we briefly outline three of our current technologies being designed specifically for applications in education. Due to space limitations, the reader is encouraged to see our other referenced publications and our accompanying images and videos in the Appendix of this submission for more detail.

The Huggable: A New Type of Robotic Companion
The Huggable, shown in Figure 1 in the Appendix, is a new type of robotic companion being designed for applications in education, family communication, healthcare, and entertainment [5, 6]. While the exterior is that of a Teddy Bear, the Huggable is in fact a very sophisticated robotic research platform with a large number of hardware and software technologies. A full description of these technologies appears in the caption of Figure 1. Of special mention, the Huggable is being designed with a

full body, multi-modal sensitive skin [7] (shown in Figure 2) capable of detecting affective [8] and social touch [9].

The Huggable is being designed to function along a spectrum of autonomy with varying degrees of human control from a fully human operated puppet to a fully autonomous robot. In the middle space, where the robot is a semi-autonomous robot avatar, there is much potential for educational applications. Unlike the traditional dyad of child and robot, in this scenario a triad emerges which allows for a remote teacher to control the robot and interact with the child through the Huggable. Our goal is for the layers of autonomy to allow the teacher to focus on the interaction without the high cognitive load required if the Huggable were a fully human controlled puppet.

Figures 3 and 4 in the Appendix present three different systems we have developed for controlling the Huggable [6, 10]. The Website Interface allows the teacher to see and hear the child through the eyes and ears of the Huggable while allowing the teacher to understand how the child is interacting with the robot as well as to control the robot's focus of attention or playback animations. The Wearable interface allows for the teacher to have a direct mapping of his or her joints to the degrees of freedom (DOFs) on the Huggable. The Sympathetic Interface is a tangible interface which allows direct control of the Huggable's DOF through direct manipulation of a matching set of DOFs on the Interface. Please see the figure captions for a more detailed description of these technologies.

We believe that the Huggable offers some interesting potential benefits. First the size and form of the Huggable may allow for the child to treat the Huggable as a learning companion and thus try to teach the robot. Additionally, we may see a similar effect as the Reading with Rover program [11], as the Huggable may be a comforting presence to the child . The form factor of the Teddy Bear also opens the door to fantasy play. Another important benefit is that the various control interfaces allow for the Huggable to share and direct attention of the child, as described in [6]. Additionally, as the Huggable features a teacher in the loop, if the child were to be spontaneous or divert from the lesson, the Huggable could still interact with them, as well as to keep the child engaged in the lesson. Finally, the Huggable could be used as a data collection device or paired with other technologies in the classroom to help assess the progress of a child as they develop the important foundations for their education in preschool.

Tofu and Mochi: Robotic Character Construction Kits

As shown in Figures 5-7, Tofu [12] and Mochi are both characters belonging to a Robotics Character Construction Kit being developed to enable new ways to scaffold child creativity and learning through storytelling. Named after Japanese food products, Tofu and Mochi are known more generally as WasabiBots. The simplest interaction with a WasabiBot consists of children dressing up the character in different ways by changing the robot's fur covering and accessories. Use of traditional videogame controllers enables children to operate WasabiBots as high functioning puppets. By interacting with a child friendly computer interface (still in development), children are given the ability to add functionality to the robotic characters. Programs designed by the child define the way physical inputs such as joysticks and buttons are mapped to the robot's behavior. Such programs could be as simple as a wink behavior or as complicated as a dance routine. While developing the story told with the WasabiBots, important critical thinking skills are being taught through use of the programming interface. Online communities could provide a way for children to develop collaboratively and exhibit their work.

The Illustrated Primer: A New Type of Smart Book

The Illustrated Primer, shown in Figure 8, is a storytelling system that visualizes stories as they are told. The primer is an ongoing development of research into the creative play of storytelling. The hardware consists of a touch screen tablet running Flash multimedia authoring software and Vista voice recognition. As the story is read aloud by the child, the voice recognition software parses what is said. As the speaker continues, the story is animated, with variation based on the word choice, amplitude and pitch of the voice. The teacher or the students can touch the screen, and cause the animations to change. Because the book responds to the words and actions done to it, the story is responsive to the spirit of the interaction between the children, storyteller and Primer. When a new word is substituted from the original story, or a character is touched, the text and graphics respond to demonstrate the effect of selecting different words or the context of the word in the scene. The benefit of this system is that the normal question and answer, and use of new vocabulary is encouraged by the system. Another benefit of this system is that reading will be more interactive and engaging. The children have a personalized and unique retelling of the story each time, and they will be encouraged to contribute to the story. The stories will change over time as each story will become more descriptive over time as the children's language skills evolve.

THE ROBOTIC PRESCHOOL OF THE FUTURE

In our vision of the preschool of the future, the three previously described systems would be integrated with one additional technology – the Magic Easel, a large multi-touch display with an integrated video camera and speakers which covers one entire side of the preschool's easel. This display can be used to display lessons, movies, or story book pages, for collaborative drawing by the children, to run the Primer software system, and to be used for two-way video conferencing. Please note in our proposed scenarios we do not see technology as a replacement for the current methods of preschool education, but rather it becomes one of the tools along with crayons, blocks, and toys that a teacher or student can use in the learning process.

The Huggable as Collaborative Storyteller

As part of the early development of the Huggable robot, time was spent talking with young children and teachers in preschool, as shown in Figure 9. Of the many positive discussions, one interesting suggestion was that the Huggable could be used as a collaborative storyteller, as described in the artist rendering of Figure 10.

Unlike other systems, where the child is a passive listener to the technology, the Huggable, in a semi-autonomous mode, would actively engage the children in collaborative storytelling. For example, as pages from the story are presented on the Magic Easel running the Primer software, the Huggable could ask the children what color the house should be, what the name of the main character should be, and other questions to engage the children in the story as well as teach them important learning foundations. This information would change in real time as the story was created. Thus, while the activity may have started with the Huggable talking to the children, it will most likely end with the children talking to one another and the Huggable to create the story. Finally, at the end of story time each child would receive a copy of the story they created together to bring home to their parents for their own story time.

Involvement of Children at Great Distances

One potential challenge for any school system, especially in the very early formative years of preschool is how to involve children who may be at great distances from the nearest school or due to illness unable to attend the class. One potential solution would be to use the 2-way video conferencing capability of the Magic Easel to bring in students to the classroom. Using their own home computer they can engage in the lesson, possibly changing the story along with their classmates or controlling aspects of the Primer or WasabiBots from home.

Another potential solution could include the use of the Huggable in the child's own home or hospital room. Here a remote tutor would use the Huggable in a semi-autonomous mode to teach the child. The robot would be paired with the child's own home or hospital computer monitor to display a lesson. A further discussion of this scenario appears in [6].

Putting on a Robotic Play

In this application, the children take the collaborative storytelling scenario and embody it using the WasabiBots and the Primer as well as clay, crayons, toys, and paper to bring it to life, as depicted in the artist's rendering of Figure 11. A benefit of this system is that the children are the creators of their own fantasy world and combine the development of motor skills in building and dressing the WasabiBots with the creativity of designing the backdrops using the Primer. Additionally, the class must work together as a team to put on the play. Finally, because the Huggable can be backdriven and used as a Sympathetic Interface, the child in the Hospital can use his Huggable robot to control the Huggable robot in the classroom and be a part of the play as well.

Other Applications

There are many other applications which can be imagined for the Robotic Preschool of the Future. First, the Magic Easel can be used to conduct show and tell at a distance. For example, children can have their parents or family members join the class on the Magic Easel. Guest lecturers can visit the class through the Magic Easel from anywhere in the world. In fact, there is the potential for virtual characters using the same control interfaces of Figures 3 and 4 originally developed for the Huggable to visit the class and take part in the experience. The Huggable could also be used to teach children a second language or for other more traditional learning [6]. Finally, the Primer could be used for collaborative drawing and storytelling as shown in Figure 12.

CONCLUSION

In this paper we have presented three technologies currently in development in the Personal Robots Group at the MIT Media Lab. We have also described how these systems could be combined to promote learning through creative fantasy play and storytelling. Our vision is that these technologies can further provide a sense of magic to the children and make a fantastic compliment to the other learning tools present in their daily preschool life.

ACKNOWLEDGMENTS

The authors would also like to thank the other members of the Personal Robots Group at the MIT Media Lab. The authors thank Fardad Faridi for providing the artist renders that accompany this document in the Appendix. We would like to also thank Daniel Bernhardt of Cambridge University. The Huggable is funded in part by a Microsoft iCampus Grant, the MIT Media Lab Things that Think and Digital Life Consortia as well as the Center for Future Storytelling. Jun Ki Lee appreciates his support from a Samsung Scholarship. We would also like to thank Don Steinbrecher for his support of the Huggable project.

REFERENCES

1. V. G. Paley, A Child's Work: The Importance of Fantasy Play: University of Chicago Press, 2005.
2. A. C. Clarke, Profiles of the Future, 1961.
3. M. U. Bers, Blocks to Robots: Learning with Technology in the Early Childhood Classroom. New York, NY: Teachers College Press, 2008.
4. F. Tanaka, A. Cicourel, and J. R. Movellan, "Socialization Between Toddlers and Robots at an Early Childhood Education Center," Proceedings of the National Academy of Science of the USA (PNAS), vol. 104, pp. 17954-17958, November 2007 2007.

5. W. D. Stiehl, J. Lieberman, C. Breazeal, L. Basel, L. Lalla, and M. Wolf, "Design of a Therapeutic Robotic Companion for Relational, Affective Touch," in IEEE International Workshop on Robot and Human Interactive Communication (RO-MAN 2005), Nashville, TN, 2005.
6. J. K. Lee, R. L. Toscano, W. D. Stiehl, and C. Breazeal, "The Design of a Semi-Autonomous Robot Avatar for Family Communication and Education " in IEEE International Workshop on Robot and Human Interactive Communication (RO-MAN 2008) 2008.
7. W. D. Stiehl and C. Breazeal, "A "Sensitive Skin" for Robotic Companions Featuring Temperature, Force, and Electric Field Sensors," in IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2006), Beijing, China, 2006.
8. W. D. Stiehl and C. Breazeal, "Affective Touch for Robotic Companions," in First International Conference on Affective Computing and Intelligent Interaction, Beijing, China, 2005.
9. H. Knight, "The Role of Touch in Social Communication for Robots," in MIT EECS MEng Thesis 2008.
10. J. K. Lee, "Affordable Avatar Control System for Personal Robots," in MIT Media Arts and Sciences, Master Of Science Thesis 2009.
11. "http://www.readingwithrover.org/."
12. R. Wistort and C. Breazeal, "TOFU: A Socially Expressive Robot Character for Child Interaction," in 8th International Conference on Interactive Design and Children (IDC2009) Como, Italy, 2009.
13. W. D. Stiehl, J. K. Lee, C. Breazeal, M. Nalin, A. Morandi, and A. Sanna, "The Huggable: A Platform for Research in Robotic Companions for Pediatric Care " in Workshop on Creative Interactive Play for Disabled Children held at the 8th International Conference on Interaction Design and Children (IDC2009) Como, Italy, 2009.

List of Appendices:

A1. CV of Authors

A2. Figures to accompany the proposal

A3. Descriptions of Videos which accompany the proposal

A4. A list of publications provided to support this proposal

A5. A list of past demonstrations of the systems described in this proposal

A1. Short CV of Authors:

1. WALTER DAN STIEHL:

Please see http://web.media.mit.edu/~wdstiehl/ for full CV including list of publications and invited talks

Education:

M.S. in Media Arts and Sciences, *Massachusetts Institute of Technology*, Cambridge, MA	2005
B.S. in Mechanical Engineering, *Massachusetts Institute of Technology*, Cambridge, MA	2003
B.S. in Brain and Cognitive Science, *Massachusetts Institute of Technology*, Cambridge, MA	2003
Certificate of Completion for Silicone Master Class and Workshop, taught by Tom McLaughlin (veteran special fx technician of over 50 films including *Babe* and *The Dark Crystal*), held at UCLA in Westwood, CA, June 24^{th}-25^{th}, 2000	2000
Certificate of Completion in Special Make-Up Effects, *Make-up Designory*, Burbank, CA	1999

Academic Appointments:

MIT Media Laboratory Research Assistant, Personal Robots Group (Formerly Robotic Life Group) Advisor: Professor Cynthia Breazeal	2003 – present
MIT Media Laboratory UROP, Personal Robots Group (Formerly Robotic Life Group) Advisor: Professor Cynthia Breazeal	2001-2003
MIT Media Laboratory UROP, Synthetic Characters Group Advisor: Professor Bruce Blumberg	1998-2001

Honors and Awards:

Invited to attend Microsoft Faculty Summit, Redmond, Washington	2008
Selected to attend the HRI Pioneers Workshop, Washington, D.C.	2007
First Ever "Robots At Play" Award for the Huggable Project, Presented in Odense, Denmark	2006
Best Paper Award IEEE RO-MAN 2005, Nashville, TN	2005
Highlands and Islands Media Lab Fellow	2005 – 2006
Microsoft iCampus Grant for the Huggable: Phase 2 Project	2005 – 2006
Microsoft iCampus Grant for the Huggable Project	2004 – 2005
Honorable Mention, National Science Foundation Graduate Research Fellowship	2005

2. ANGELA CHANG

Please see http://web.media.mit.edu/~anjchang/ for full CV including list of publications and invited talks

Education:

M.S. in Media Arts and Sciences, *Massachusetts Institute of Technology*, Cambridge, MA	2002

B.S. in Mechanical Engineering, *Massachusetts Institute of Technology*, Cambridge, MA 1997

Academic Appointments:

MIT Media Laboratory 2005 – present

Research Assistant, Personal Robots Group (Formerly Robotic Life Group)

Advisor: Professor Cynthia Breazeal

MIT Media Laboratory 2000-2002

Research Assistant, Tangible Media Group

Advisor: Professor Hiroshi Ishii

Honors and Awards:

Samsung Fellow . 2008-2009

CHI 2008 Doctoral Consortium 2008

Toshiba Fellow 2001-2002

3. RYAN WISTORT

Please see http://web.media.mit.edu/~rwistort/rybots/index.html for full CV including list of publications

Education:

B.S. in Electrical Engineering, *University of Washington*, Seattle WA, 2007

Academic Appointments:

MIT Media Laboratory 2008 – present

Research Assistant, Personal Robots Group (Formerly Robotic Life Group)

Advisor: Professor Cynthia Breazeal

Honors and Awards:

Mary Gates Research Scholar . 2003

NASA Space Grant Scholar 2003

4. CYNTHIA BREAZEAL

Please see http://web.media.mit.edu/~cynthiab/index.html for full CV including list of publications and invited talks

Education:

Sc. D. in Electrical Engineering and Computer Science, *Massachusetts Institute of Technology*, Cambridge, MA 2000

S.M. in Electrical Engineering and Computer Science, *Massachusetts Institute of Technology*, Cambridge, MA 1993

B.S. in Electrical and Computer Engineering, *University of California* 1989

Academic Appointments:

MIT Media Laboratory April 2009 – present

Tenured Professor of Media Arts and Sciences

LG Professor of Media Arts and Sciences (chair)

Director of the Personal Robots Group at the MIT Media Laboratory

MIT Media Laboratory July 2005 – April 2009

Associate Professor of Media Arts and Sciences

LG Professor of Media Arts and Sciences (chair)

Director of the Personal Robots Group at the MIT Media Laboratory

MIT Media Laboratory July 2001 – June 2005

Assistant Professor of Media Arts and Sciences

LG Professor of Media Arts and Sciences (chair)

Director of the Robotic Life Group at the MIT Media Laboratory

MIT AI Laboratory 2000 – June 2001

Postdoctoral Associate

Selected Honors and Awards:

Robot Design Competition, Gold Prize (Ro-Man 2007)	2007
New Technology Foundation Finalist for Entertainment Robots and Systems (IROS 2007)	2007
10K Euro Robots at Play Prize	2006
Office of Naval Research Young Investigator Award	2005
ALA Achievement Award	2004
Finalist National Design Award in Communication	2003
Commonwealth 21st Century Award for Innovation	2003
Technology Review TR35 (formerly TR100) for Outstanding Young Innovators	2003
Richard Saul Wurman's *1000*, Most Creative People in the USA	2002
Boston Business Forward, Top 40 Most Influential Young People	2001
New York Academy of Sciences, Outstanding Young Woman Scientist	2001
George Sprowles Award for Outstanding Doctoral Thesis in EECS	2000
NASA Graduate Student Researchers Program Fellowship	1992—1994

A2. Figures to Accompany the Proposal:

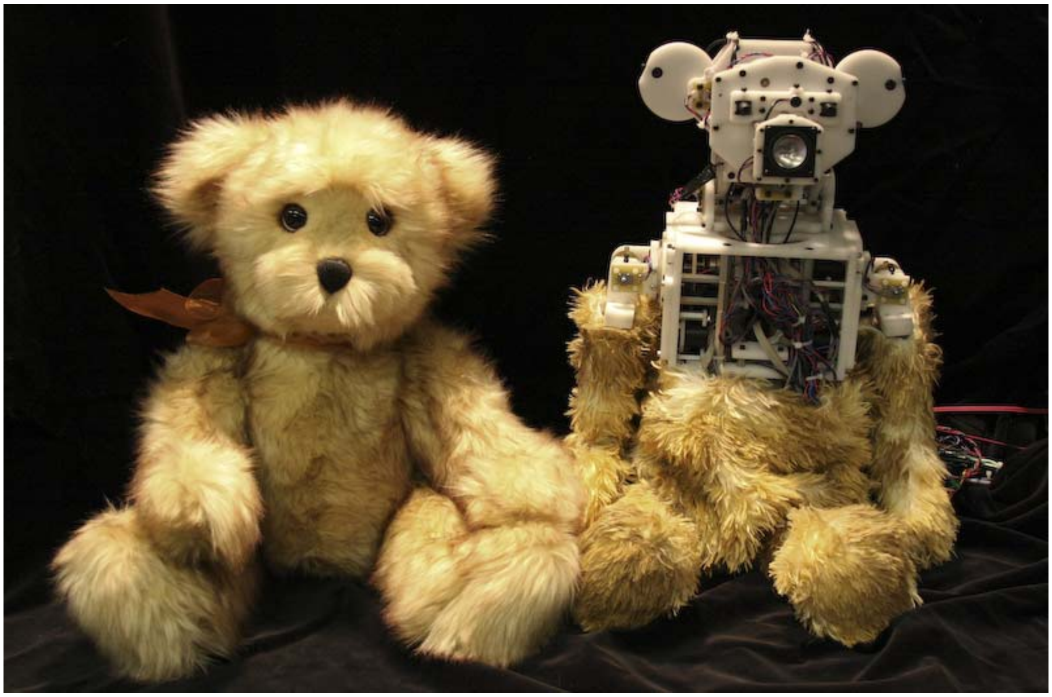

Figure 1. The Current Huggable V3.0 Prototype (in development) (right) and the Concept Plush (left). In the current prototype only the underlying mechanics of the robot are shown. The sensitive skin system, soft silicone rubber beneath the fur, and final cosmetic fur exterior are not shown in this photo. When fully finished it will look like the concept plush at left. In the head of the robot is an array of microphones, two cameras in the eyes (one color and one black and white), and a speaker in the mouth. In the body, the Huggable features an inertial measurement unit (IMU), passive potentiometers in the hips and ankles for joint position sensing, and an embedded PC with wireless networking. The Huggable currently features eight degrees of freedom (DOF) – a 3-DOF neck (nod, tilt, and rotate), a 2-DOF shoulder mechanism in each arm (rotate and in/out), and a 1-DOF ear mechanism. These degrees of freedom are all designed with a quiet and back-drivable transmission for safety and to not distract from the interaction with the traditional gear noises associated with many robot systems.

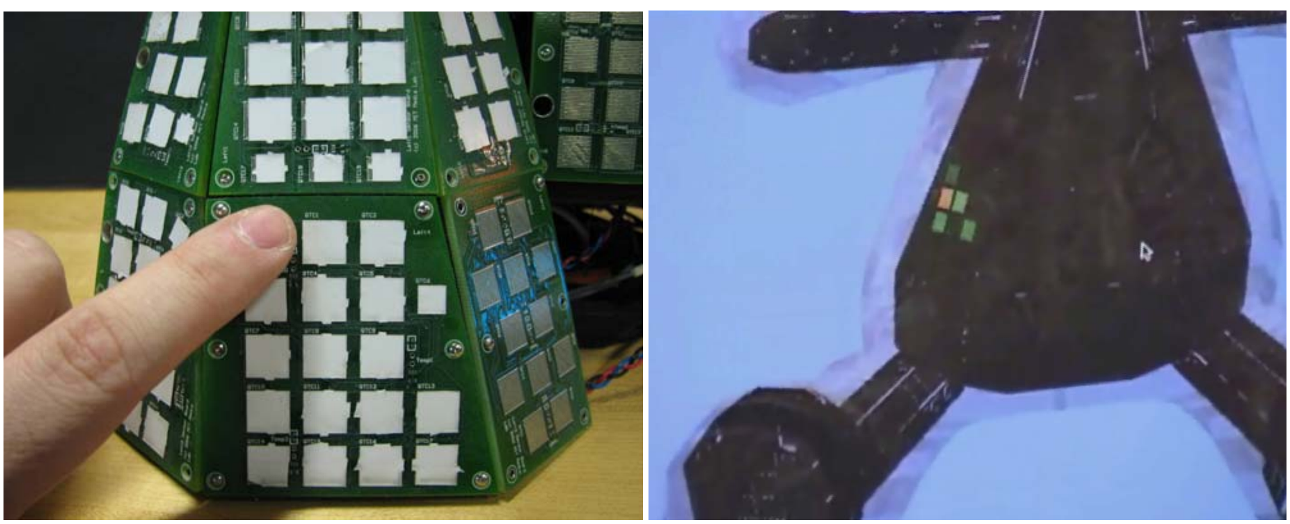

Figure 2. The Sensitive Skin and Display of Touch on the 3D Virtual Model of the Huggable. At left is the side panel sensitive skin from the 2nd generation Huggable robot with a human index finger shown for scale. The skin consists of 3 types of sensors - pressure (white squares), temperature (small 0402 thermistors), and electric field sensors (electrodes on the bottom sides of the boards (not shown)). This sensor panel is below a layer of soft silicone rubber and fur in the actual robot system (not shown). At right is shown the display of sensor output from the sensitive skin (from light green to red) on the 3D Virtual Model of the Huggable. In this image, the teddy bear texture is set to transparent so as to show the response more clearly. Please note that the touch applied in the left and right images do not match.

.

Figure 3. A Screen-Shot of our Current Web Interface. The lower left portion is the stale panorama. On the stale panorama, the blue window on the left side of the panorama shows the target position where the operator wants the Huggable to look next and the yellow window in the upper right shows the Huggable's current live camera feed. Across the top of the website from left to right are: 1.) a series of options (such as turning on face detection) which can be used by the operator, 2.) the play sound and text to speech audio functions which the operator can use to play back sound effects or talk to the user through the Huggable (in addition to using the worn headset microphone), 3.) the motion state animated 2D graphic which displays an animation based on the classified output of the IMU (i.e. rocking, picked up, bouncing, etc), and 4.) the virtual Huggable 3D WYSIWYG representation of the current motion of the Huggable robot as well as any interactions such as the user wiggling the Huggable's feet, the current orientation the robot is held in, or where the robot is being touched (as shown in Figure 2). Below the virtual Huggable are a series of animations which can playback on the Huggable with the operator's mouse click.

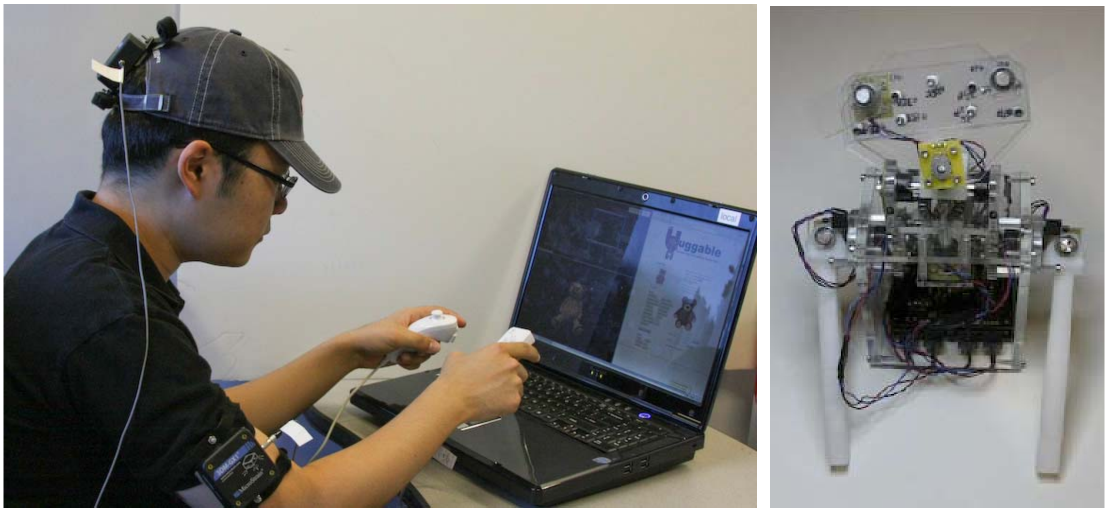

Figure 4. The Wearable Interface and Sympathetic Interface. In the wearable interface (left), the human operator holds a Wii Remote and a Nunchuk on both hands and wears a set of orientation sensors on both arms and the head. The prototype Sympathetic Interface (right) has potentiometers at each of the 8-DOF corresponding to the Huggable's points of motion (3-DOF neck, 2-DOF shoulder in each arm, and 1-DOF ears). The Sympathetic interface will ultimately be in a soft plush bear exterior. One important benefit of our system is that the layers of autonomy allow for the teacher to control one degree of freedom (i.e. the left arm) while the other degrees (i.e. head and right arm) continue to move in a lifelike way

Figure 5. General Tofu Robot Control Interface. As shown, the current version of the Tofu robot is controlled through a puppeteering interface. Game controller inputs are read from the small laptop shown and used to control the robot's behavior. Buttons on the interface can also be used to trigger complex animations.

Figure 6. General Mochi Robot Control Interface. As shown, the current version of the Mochi robot is composed of a similar expressive body as the Tofu robot. In addition, the Mochi robot has a circular omnidrive base and an added degree of freedom in the head. The wireless and battery powered robot is also controlled through a joystick interface. A single OLED display is used to generate the robot's eye motions.

Figure 7. Tofu and Mochi Robot Expression Examples. Through use of a deformable body, the Tofu robot (at top) is capable of a wide range of expressions. A four motor system consisting of three motors in the base and one in the head are used to generate these motions. Two small OLED displays are used to generate dynamic eye motions. The current version of the Mochi robot (at bottom) is capable of several unique expressions as shown. By combining a lean backwards/forwards motion with a head look up/down, the robot is able to convey engagement and disengagement as shown.

Figure 8. Interactions with the Illustrated Primer. At top, moving a finger over the text highlights the semantically relevant content. In the middle figures, the reader can add to the story using a stylus (or keyboard, not pictured), causing graphics to be visualized on the stage. At bottom, gestures on the screen cause the story to advance to the next scene. Please note that in this image, interactions are done using a multi-touch tablet PC, but the software would also run on the Magic Easel of our proposal.

Figure 9. Early Focus Groups for the Huggable Robot held at Preschool. Here during their circle time children were given stuffed Teddy Bears and asked what they would like their bear to do if it were to magically come to life. Additionally, teachers were asked how the Huggable robot could be beneficial in the classroom. Findings from this early focus group helped to develop aspects of this proposal. We thank Highlands and Islands Enterprise of Scotland for their help in arranging this visit and for securing the permission to use images from the visit in our publications.

Figure 10. Artist Drawing of the Huggable as Collaborative Storyteller. Here the Huggable robot joins the class in circle time to work on a collaborative story together. As shown in the figure, the Huggable sits next to the Magic Easel in a spot around the circle on the floor with the primary teacher and other children. The Huggable functions in the semi-autonomous case with a teaching assistant controlling the robot and the Magic Easel display running the Primer software from another room in the school. The story appears on the Magic Easel and is controlled using the Primer software to allow for real time interactivity as the story is collaboratively built by the class. Image Credit: Fardad Faridi.

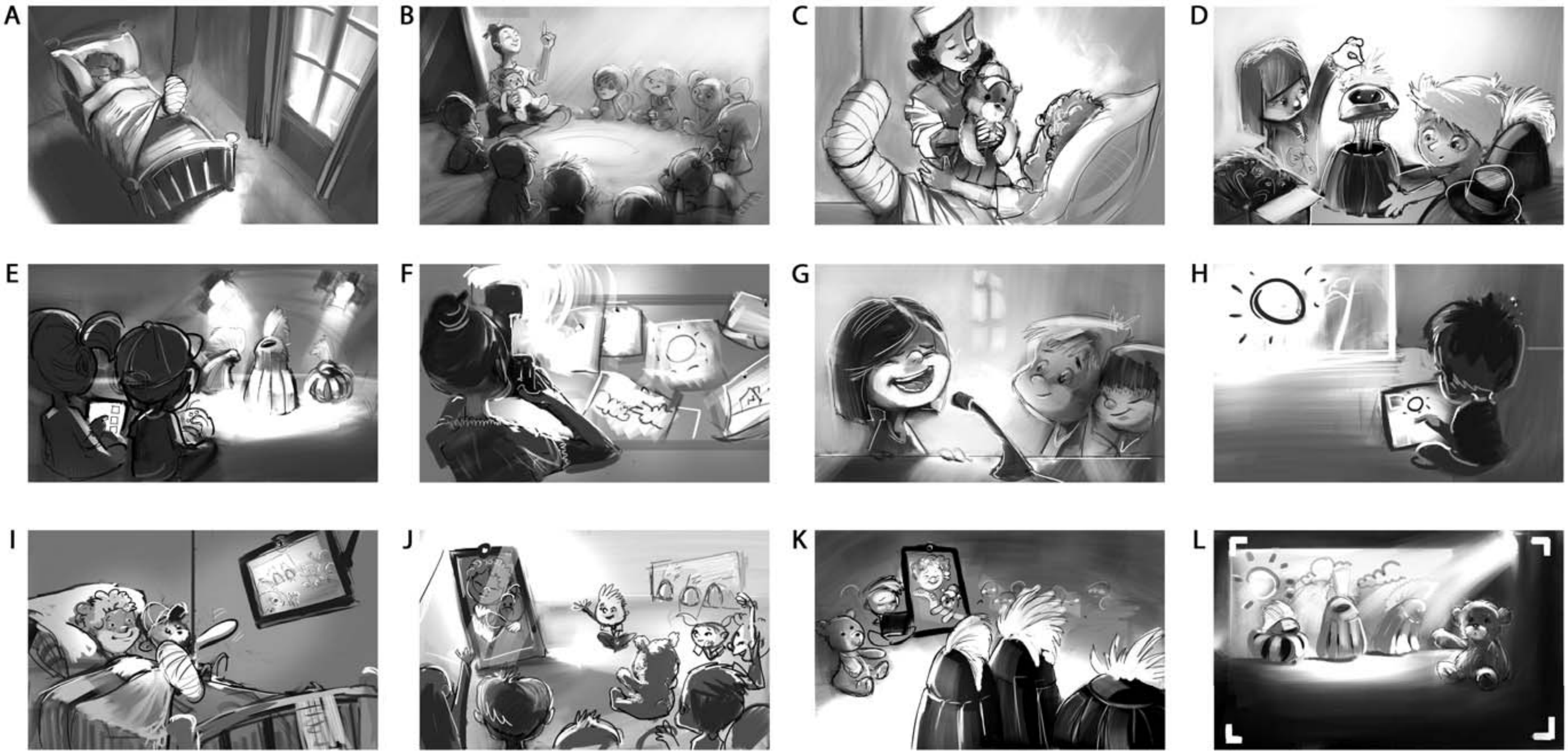

Figure 11. Putting on a Robotic Play. A.) In this scenario, one of the classmates has broken his leg and will be away from his friends and teachers at preschool. B.) Missing their classmate, the teacher asks the class what they should do to make their friend feel better. The class decides to put on a play for their friend to try to cheer him up. C.) Meanwhile, in the hospital, the child has received a version of the Huggable robot from a nurse in the pediatric unit as described in [13]. Back in the preschool, the class is divided up into small groups with each group having a specific part of the play they are responsible for. D.) One group is in charge of making the main characters using the WasabiBots. E.) Once the robots are dressed with a mix of fabrics and other materials, another group of students works on bringing the characters to life and controlling the lighting of the stage through the Character Construction Kit software and a gamepad. Other children are responsible for drawing the backgrounds or making other set pieces out of clay and other items. F.) The hand drawn sketches are photographed by the teacher and combined with sketches already drawn on the Magic Easel. G.) In another area of the classroom a small group of children record the sound effects and other audio for the play. H.) Other children use the Primer software running on a kid-friendly tablet to experiment with the projected backgrounds and scenes on the back of the stage to find the right look and feel. Finally, all the elements are assembled on the stage, and the class calls their friend in the hospital on the Magic Easel with their surprise. I.) The Huggable in the child's room in the hospital receives the call and alerts the child that he has a surprise. J.) On a monitor in his room, he sees and hears his classmates at the preschool and they can see him on their Magic Easel. In addition, the Huggable in the hospital room can be used as a Sympathetic Interface. Thus the child in the hospital can control the Huggable in the preschool classroom and take part in the play as well. K.) It is now time for the show, as the Magic Easel is turned to face the stage. L.) On the stage the main WasabiBot characters perform in front of animated scenes created by the Primer software and the Huggable, controlled by the child in the hospital, takes park in the play. Please note this sequence also appears in Video V13 Image Credit: Fardad Faridi.

Figure 12. Using the Magic Easel For Collaborative Play. Using the multi-touch surface of the Magic Easel, children can draw together and tell their own stories using the Primer software.

A3. Descriptions of Videos Which Accompany the Proposal:

All Video Files can be downloaded from http://web.media.mit.edu/~wdstiehl/IDC_C4C/. We kindly ask that these videos are not distributed outside of the competition judges without first contacting the authors of this submission. Many of these videos show work still in progress which has not been publicly shown before and is not ready for wide distribution. Thank you.

V1. A Day in the Life of the Huggable:

Filename: Day_In_Life_Short_wmv_640x480.wmv

Description: In this video we provide an overview of the current 3rd Generation Huggable robot and demonstrate the various hardware and software systems of the robot. Please note that the Website Interface shown in this video is an earlier version of the Website Interface of Figure 3.

V2. The Huggable Sympathetic Interface:

Filename: Sympathetic_Interface_Tech_Demonstration.wmv

Description: In this video we demonstrate the control of the 3rd Generation Huggable robot using the Sympathetic Interface prototype. Of note is that the robot remains active even when not directly controlled, showing the layers of autonomy present in the system. This video does not have sound.

V3. The Huggable Sensitive Skin:

Filename: SkinComplete.wmv

Description: In this video, we demonstrate the Sensitive Skin system developed for the 2nd Generation Huggable robot. This system will be revised for inclusion in the 3rd Generation robot this summer.

V4. Technical Demonstration of the IMU sensing system:

Filename: IMU_Tech_Demonstration_wmv_640x480.wmv

Description: In this video, we demonstrate how the IMU sensor inside the Huggable is used to rotate the 3D Virtual Huggable on the Website Interface. In addition, we demonstrate the classification of different gestures and the display of these classified gestures on the Website Interface. Please note that the Website Interface shown in this video is an earlier version of the Website Interface of Figure 3. This video also does not have sound.

V5. Technical Demonstration of the Look-at Foot Behavior based on Potentiometer Sensing in the Legs:

Filename: Pots_Lookat_Tech_Demonstration_wmv_640x480.wmv

Description: In this video, we demonstrate how a person playing with the Huggable's foot is sensed by the potentiometers in the legs. This causes the robot to execute a Look At behavior towards it's own foot. In addition, the motion of the foot is displayed on the Website Interface to let the operator know the child is moving that joint. Please note that the Website Interface shown in this video is an earlier version of the Website Interface of Figure 3. In the current version, the 3D Virtual Huggable's ankle moves in real-time as the robot's foot is moved. In addition, we play to show similar Look At behaviors when the robot is touched once it is outfitted with the full body sensitive skin of Figure 2 and Video V3. This video also does not have sound.

V6. Technical Demonstration of Wearable Puppeteering Interface:

Filename: Puppeteering_Tech_Demonstration_wmv_640x480.wmv

Description: In this video, we demonstrate two methods of control of the Huggable robot using the Wearable Interface. In the first part of the video, we demonstrate direct control of the Huggable robot and virtual Huggable robot. In the second part of this video we demonstrate gesture based control of the Huggable robot.

V7. Technical Demonstration of the Stale Panorama, Labeling system, and Look At based on Vision Autonomous Behavior:

Filename: StalePanorama_LookAt_Label_Tech_Demo_wmv_640x480.wmv

Description: In this video, we demonstrate three technologies on the Website Interface which help reduce the cognitive load of a teacher operating the Huggable robot in a semi-autonomous way. The first technology, the Stale Panorama, allows for the teacher to instantly click on a location for the Huggable to look. The second technology, the Labeling System, allows for the teacher to label areas of the stale panorama where specific objects or people are located and then at the click of a button direct the robot's gaze to that person or object. Finally, the Look At Face Following system causes the Huggable to use OpenCV to keep the person centered in the Huggable's field of view. These technologies allow for the teacher to focus on the interaction or instruction without the control controls of moving the robot around. Please note that the Website Interface shown in this video is an earlier version of the Website Interface of Figure 3. This video also does not have sound.

V8. Coloring Short Interaction Sequence:

Filename: Coloring_Short_Sequence_wmv_640x480.wmv

Description: In this video, we show a short sequence from V1 based on the coloring interaction. Using the Website Interface, a teacher playing the role of the Huggable can interact with a child in a coloring scenario. Please note that the Website Interface shown in this video is an earlier version of the Website Interface of Figure 3.

V9. Reading Short Interaction Sequence:

Filename: Reading_Short_Sequence_wmv_640x480.wmv

Description: In this video, we show a short sequence from V1 based on the reading interaction. Using the Website Interface, a teacher playing the role of the Huggable can read a book to a child. Please note that the Website Interface shown in this video is an earlier version of the Website Interface of Figure 3.

V10. Tofu:

Filename: tofuDemonstration.mov

Description: In this video, the expressive capabilities of the TOFU robot are shown. Body movements are generated by deforming the robot's foam body with servo motors. Small displays used for eyes allow the robot to have dynamic eye motions. By utilizing animation techniques such as "squash and stretch" the robot is able to emulate the illusion of life commonly found in animations.

V11. Mochi:

Filename: mochiDemonstration.mov

Description: In this video, the Mochi robot is puppeteered to show the range of expression that the robot is capable of. The body and head of Mochi is similar to the deformable TOFU robot, with the addition of a elevation degree of freedom in the neck. A display in the robots face is used to create dynamic eye motions. Use of an omnidrive base allow the robot to translate and rotate physically.

V12. Interactions with the Illustrated Primer:

Filename: IllustratedPrimer5.mov

Description: In this video we demonstrate the multi-modal interactions available with the Illustrated Primer.

V13. Concept Video for the Robotic Preschool of the Future:

Filename: IDC_Robotic_Preschool_of_Future.mov

Description: This video is an artistic depiction of the Creation of a Robotic Play example described in this submission and in Figure 11.

A4. A List of Publications Provided to Support this Proposal (Available upon Request)

HUGGABLE ROBOT:

Theses:

J. K. Lee (2009), Affordable Avatar Control System for Personal Robots. Master of Science thesis. Media Arts and Sciences, MIT.

R. Toscano (2008) Building a Semi-Autonomous Sociable Robot Platform for Robust Interpersonal Telecommunication. MEng Thesis, Electrical Engineering and Computer Science, MIT.

H. Knight (2008), The Role of Touch in Social Communication for Robots. MEng Thesis, Electrical Engineering and Computer Science, MIT.

N. A. Akraboff (2008), Design of Transmission Mechanisms for the Head of the 'Huggable' Robotic Teddy Bear. Bachelor of Science thesis. Mechanical Engineering. MIT.

L. Lalla (2006), A Design of Actuation Mechanisms for Use in 'Huggable' Robotic Teddy Bear. Bachelor of Science thesis. Mechanical Engineering. MIT.

W. D. Stiehl (2005), Sensitive Skins and Somatic Processing for Affective and Sociable Robots Based Upon as Somatic Alphabet Approach. Master of Science thesis, Media Arts and Sciences, MIT.

Journal Articles:

J. K. Lee, W. D. Stiehl, R. L. Toscano, and C. Breazeal, "Semi-Autonomous Robot Avatar as a Medium for Family Communication and Education", Advanced Robotics (*in review).*

Conference Papers:

W. D. Stiehl, J. K. Lee, C. Breazeal, M. Nalin, A. Morandi, and A. Sanna, (2009). "The Huggable: A Platform for Research in Robotic Companions for Pediatric Care" in *Workshop on Creative Interactive Play for Disabled Children held at the 8th International Conference on Interaction Design and Children (IDC2009)* Como, Italy, 2009.

W. D. Stiehl, J. K. Lee, C. Breazeal (2009). "The Huggable Project: Building a Personal Robotic Companion System For Healthcare, Education, Family Communication, and Entertainment." CHI'09: Catz and Dogz Workshop. Boston, Massachusetts, 2009.

H. Knight, A. Chang, W. D. Stiehl, R. Toscano, Y. Wang, C. Breazeal (2009). "Robot Design Rubrics for Social Gesture Categorization and User Studies with Children" Human-Robot Interaction Conference (HRI 2009): Societal Impact: How Socially Accepted Robots Can Be Integrated in Our Society Workshop. San Diego, California, 2009.

W. D. Stiehl, J. K. Lee, et al. (2008). "The Huggable: A Platform for Research in Robotic Companions for Eldercare." AAAI Fall Symposium: AI in Eldercare. Arlington, Virginia, 2008.

J. K. Lee, R. L. Toscano, W. D. Stiehl, and C. Breazeal (2008), "The Design of a Semi-Autonomous Robot Avatar for Family Communication and Education." IEEE International Workshop on Robot and Human Interactive Communication (RO-MAN 2008), Munich, Germany, 2008.

W. D. Stiehl, C. Breazeal (2006), "A Sensitive Skin for Robotic Companions Featuring Temperature, Force, and Electric Field Sensors." Proceedings of the 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2006), pp.1952-1959, Beijing, China, 2006.

W. D. Stiehl, C. Breazeal, K. H. Han, J. Lieberman, L. Lalla, A. Maymin, J. Salinas, D. Fuentes, R. Toscano, C. H. Tong, A. Kishore, M. Berlin, and J. Gray (2006), "The Huggable: A Therapeutic Robotic Companion for Relational, Affective Touch." Emerging Technologies Abstract, SIGGRAPH 2006, Boston, MA, 2006.

W. D. Stiehl, C. Breazeal, K. H. Han, J. Lieberman, L. Lalla, A. Maymin, J. Salinas, D. Fuentes, R. Toscano, C. H. Tong, and A. Kishore (2006), "The Huggable: A New Type of Therapeutic Robotic Companion." Sketch presented at SIGGRAPH 2006, Boston, MA, 2006.

W. D. Stiehl, J. Lieberman, C. Breazeal, L. Basel, R. Cooper, H. Knight, L. Lalla, A. Maymin, and S. Purchase (2006), "The Huggable: A Therapeutic Robotic Companion for Relational, Affective Touch." presented at IEEE Consumer Communications and Networking Conference, Las Vegas, NV, 2006.

W. D. Stiehl, J. Lieberman, C. Breazeal, L. Basel, L. Lalla, and M. Wolf (2005), "The Design of the Huggable: A Therapeutic Robotic Companion for Relational, Affective Touch." presented at AAAI Fall Symposium on Caring Machines: AI in Eldercare, Washington, D.C., 2005.

W. D. Stiehl and C. Breazeal (2005), "Affective Touch for Robotic Companions." Proceedings of the 2005 First International Conference on Affective Computing and Intelligent Interaction (ACII 2005), LNCS 3784, pp. 747-754 Beijing, China, 2005.

W. D. Stiehl, J. Lieberman, C. Breazeal, L. Basel, L. Lalla, and M. Wolf (2005), "Design of a Therapeutic Robotic Companion for Relational, Affective Touch." (Best Student Paper Award) presented at IEEE International Workshop on Robot and Human Interactive Communication (RO-MAN 2005), pp. 408-415, Nashville, TN, 2005.

TOFU:

R. Wistort, C. Breazeal, (2009). "TOFU: A Socially Expressive Robot Character for Child Interaction" *8th International Conference on Interaction Design and Children (IDC2009)* Como, Italy, 2009.

A5. A list of past demonstrations of the systems described in this proposal

HUGGABLE ROBOT:

"The Huggable": Interactive Demonstration of Third Generation Prototype at TheFunded Event, MIT Media Lab, Cambridge, MA, March 10, 2009. 2009

"The Huggable": Interactive Demonstration of Third Generation Prototype at RoboDevelopment 2008 in the Microsoft Robotics Developers Studio Booth. Santa Clara Convention Center, Santa Clara, CA, November 18-19, 2008. 2008

"The Huggable": Static Display of Second Generation Huggable Prototype. Star Wars Where Science Meets Imagination. International Touring Exhibit. 2008-

"The Huggable": Interactive Demonstration of Third Generation Prototype at the San Raffaele Del Monte Tabor Foundation (HSR), Milan, Italy, May 6-7, 2008. 2008

"The Huggable": Interactive Demonstration of Second Generation Prototype at the Space Between: Making Connections during Palliative Care Conference Sponsored by the Highland Hospice, Inverness, Scotland, November 8th-9th, 2007 2007

"The Huggable": Interactive Demonstration of Second Generation Prototype at the "Our Cyborg Future?" Exhibition as part of the Designs of the Time 2007 Festival, Newcastle, UK, October 19th, 2007 2007

"The Huggable": Interactive Demonstration of Second Generation Prototype at the AARP Life@50+ Conference, Boston, MA, September 6th-8th, 2007 2007

"The Huggable": Interactive Demonstration of Second Generation Prototype at the Robots at Play Festival, Odense, Denmark, August 23rd-25th, 2007 2007

"The Huggable": Static Display and Interactive Touch Sensor Panel as part of the "Our Cyborg Future?" Exhibition as part of the Designs of the Time 2007 Festival, Newcastle, UK, August 10th-October 27th, 2007. 2007

"The Huggable": Interactive Demonstration of Second Generation Prototype during Microsoft Keynote at RoboBusiness 2007, Boston, MA, May 16th, 2007. 2007

"The Huggable": Booth at the World Healthcare Innovation and Technology Congress Washington, DC, November 1st-3rd, 2006 2006

"The Huggable": Interactive Technology Demonstration at Disney New Technology Forum: Best of SIGGRAPH 2006 at the Walt Disney Studios in Burbank, CA September 8th, 2006 — 2006

"The Huggable": Interactive Technology Demonstration in Emerging Technologies Pavillion at SIGGRAPH 2006, Boston, MA, July 30th-August 3rd, 2006 — 2006

"The Huggable": Static Display and Interactive Touch Sensor Panel as part of the "Tech'ing it to the Next Level: Highlights from iCampus, the MIT-Microsoft Alliance" Exhibition, MIT Museum, Cambridge, MA, May 23rd – December, 2006 — 2006

"The Huggable": Booth and Focus Groups at The Digital Future – Creativity without Boundaries Conference, Aviemore, Scotland, May 11th, 2006 — 2006

"The Huggable": Technology Demonstration at the IEEE Consumer Communications and Networking Conference, Las Vegas, NV, Jan 9-10, 2006. W.D. Stiehl, J. Lieberman, C. Breazeal, L. Basel, R. Cooper, H. Knight, L. Lalla, A. Maymin, and S. Purchase. — 2006

"The Huggable": Technology Demonstration at Microsoft Research Faculty Summit, Microsoft Conference Center, Redmond, WA, July 19th, 2005. — 2005

TOFU:

"Tofu": Classroom demonstration of Tofu robot in a pre-kindergaren class, Cambridge, MA, April 9th, 2009 — 2009

"Tofu": Public demonstration of Tofu robot in an art studio setting, Cannytrophic Design Expo, South Boston, MA, March 28th, 2009 — 2009

"Tofu": On stage demonstration of Tofu system interacting through Puppeteering Interface, Awareness Fall 2008 Meeting: Research Update MIT Media Lab, Cambridge, MA, October 29th, 2009 — 2009