Designing for Children
- With focus on 'Play + Learn'

Designing Toys and Technologies for Rehabilitation

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Abstract: Brain injury, cerebral palsy and other neurological conditions create profound movement disorders in children, often leading to impaired use of the arm. Rehabilitation with physical therapy is critical for functional recovery. New rehabilitation techniques based on recent neuroscientific advances have been suggested to enhance recovery and to promote brain plasticity in patients following brain damage. These rehabilitation techniques, however, have not focused on children nor have emerging methods, such as constraint-induced therapy, capitalized upon the primary learning avenue for children - playing.

Our goal is to design, develop and evaluate toys that incorporate rehabilitation technologies to encourage continued use of affected muscle groups within a principled scientific framework. These novel toys using state-of-the-art technology are designed to incorporate new strategies in the therapy of the upper extremity. In addition, these "toy-based-technologies" will record play activity to allow clinicians and therapists to track the patient's progress and evaluate rehabilitation efficacy through objective quantitative approaches, leading to new hypothesis-driven rehabilitation approaches.

Key words: cerebral palsy, rehabilitation, toys, technology, design, interdisciplinary

1. Introduction

The premise of this project is that increased therapy in the form of play, targeted to the affected muscle groups with the possibility of neuro-feedback, will provide greater long lasting functional recovery in the pediatric population. An additional goal for this project is to design, develop, and prototype a line of toys and related technologies, evaluate their use, and collect pilot data necessary to obtain ongoing project funding. The innovations developed through this project have the potential to substantially enhance and provide a scientific base for developing and implementing rehabilitation therapies in children, and to improve the quality of life, self-care, and independence of children with disabilities.

The Designing Toys and Technologies for Rehabilitation project, with an unique collaboration of scientists, clinicians, designers and engineers from Rhode Island and Hasbro Children's Hospital, Brown University, Rhode Island School of Design, Afferent Corporation, and Bay Computing Associates, began as a collaborative design studio course taught in the fall of 2006 between Brown University Engineering department and the Rhode Island School of Design, Industrial Design Department. Midway through the semester we decided to apply for a grant in order to expand and continue the development of this concept beyond the classroom. We applied for and won a RHODE ISLAND RESEARCH ALLIANCE RHODE ISLAND SCIENCE AND TECHNOLOGY COUNCIL (STAC) Grant, which went into effect starting January of 2007. This report highlights the dynamic, interdisciplinary design process that preceded the initiation of clinical studies.

2. Method:

THE BROWN/RISD TOYS FOR REHABILITATION STUDIO, FALL 2006

TOYS for REHABILITATION Course Summary Fall 2006

Instructors: J.J. Trey Crisco, Ph.D. and Khipra Nichols, B.I.D

Clinical Advisor: Karen Kerman, M.D.

Teaching Assistants: Adam Geremia and Tonia Hsieh, Ph.D.

This Design Studio combines, Industrial Design, Rhode Island School of Design and EN 193 S04, Division of Engineering, Brown University, and has been offered each year since 1996. It is meant to unite the culture of industrial design at RISD with that of engineering at Brown University as a way of introducing each to the other's methodologies. This ongoing relationship was the brainchild of the late Professor Ken Hunnibell of RISD's Industrial Design Department.

During the summer of 2006 J.J. Trey Crisco, Ph.D. Professor, Department of Orthopedics, Brown Medical School and I, Khipra Nichols RISD ID, were shaping the course around an idea proposed by

Dr. Karen Kerman, Head of Pediatrics at Hasbro Children's Hospital in Providence RI. Her thoughts are paraphrased in the course mission of the course overview as stated below:

2.1 Course Mission:

To develop novel toys designed to promote and measure recovery of function in children with movement disorders resulting from brain injury, cerebral palsy and other neurological conditions leading to impaired use of the arm. New rehabilitation techniques have been suggested to enhance recovery of function and brain plasticity in patients following brain damage. The goal is to create new kinds of toys and related products designed to help facilitate upper extremity rehabilitation while recording data that helps clinicians and therapists track the patient's progress.

2.2 Course Overview:

Phase 1: 9-14 to 10-5 Concept and Sketch Model Development

Phase 2: 10-5 to 10-31 Technology and, Human Factors Studies, Field Testing

Phase 3: 10-31 to 12-7 Final Design and Prototyping

2.3 Course Goals:

This multidisciplinary studio focused on the development of novel toys designed to promote recovery of function in children with movement disorders. New rehabilitation techniques have been suggested to enhance recovery of function and brain plasticity in patients following brain damage. The goal was to bring engineering and ID students together to create new kinds of toys and related products designed to help facilitate rehabilitation while recording data that helps therapists track the patient's progress. The studio combined concepts from clinical medicine, bioengineering and industrial design to create and test interactive toys to enhance participation and measure performance changes quantitatively. Students worked in groups of 3 or 4 and each group created 2 final designs. These groups are interdependent and semi-permeable, in that they share research information and assist each other in a non-competitive spirit. I have found this approach to be a very efficient way to generate a high level of dynamism and enthusiasm while fostering constructive cooperation. The following is a brief description of each of the student groups' final toy prototype:

2.4 The Toys

Students: Melissa Armstrong and Margaret Middleton

Toy Name: Sleevies

Play: Sleevies may be placed on either forearm of children with upper extremity disorders. Play modules of various themes are attached to brace-like structure.

Rehabilitation Goals: Encourages fine and gross use of affected upper extremity. Designed as a play alternative to immobilization of the unaffected limb in constraint-induced therapy, a therapy newly demonstrated to be an effective rehabilitation technique for children.

Electronics and Data Acquisition: Play activity recorded.

Figure.1 Sleevies and Zoo Shoes

Students: Melissa Armstrong and Margaret Middleton**Toy Name:** Zoo Shoes
Play: Fun walking shoes.

Rehabilitation Goals: Sole angulation induces dorsal flexion to help stretch posterior structures of the lower limb. Positive audio/visual feedback for heel-to-toe gait can also be provided

Electronics and Data Acquisition: Heel and toe elastic contact sensors. Number of heal-to-toe, toe only, etc. gait cycles are documented. Data can be used in real time for positive gait feedback.

Students: Nicole Latorre, Hajin Lee, Sarah Lee, Cali Schottenfeld
Toy Name: Climbing Rewards
Play: Climbing with audio/visual buttons for rewarding sequence game play.
Rehabilitation Goals: Whole body exercise. Stretching posterior components of lower limb. Upper extremity grasp.
Electronics and Data Acquisition: Reward button sequence programmable. Button activity recorded.

Figure.2 Climbing Rewards and Ice Cream Parlor

Students: Nicole Latorre, Hajin Lee, Sarah Lee, Cali Schottenfeld
Toy Name: Ice Cream Parlor

Play: Role playing with Play-doh ice cream, ice cream scooper, cones, toppings, and aprons

Rehabilitation Goals: Unique donut-shaped container induces forearm supination during ice cream scooping.

Electronics and Data Acquisition: Ice cream scooper is instrumented to record play activity.

Students: Chung Sup Lee, Mike Scherer, Alexandra Surasky-Ysasi, Liam Wager

Toy Name: Roto-Launcher Kazaam

Play: Turning cranks builds pressure. At target pressure rocket (or butterfly) is launched. Target pressure and cranking resistance can be adjusted.

Rehabilitation Goals: Upper extremity motion with forearms in neutral supination/pronation.

Electronics and Data Acquisition: Light sequences provide visual feedback for target pressure (e.g. drag racing light tree). Play activity recorded.

Figure.3 Roto- Launcher Kazaam

Students: Chung Sup Lee, Mike Scherer, Alexandra Surasky-Ysasi, Liam Wager

Toy Name: Power Glove **Play:** The Power Glove replaces conventional toy remote controls. Standard thumb controls are eliminated and are mapped to the gross movements of wrist flexion/extension and forearm supination/pronation.

Rehabilitation Goals: Eliminates need for fine motor control in standard remote control toys and encourages play with gross motor movements.

Electronics and Data Acquisition: Control is mapped to orientation sensors. Play activity is recorded.

Figure.4 Power Glove and Dino- Pull

Students: Mary Davison, Mark Drew, Idil Ince

Toy Name: Dino-Pull

Play: Toy dinosaurs can be manipulated with audio/visual feedback.

Rehabilitation Goals: Dino-Pull is a toy designed to help children with cerebral palsy gain better gross and fine motor control of the upper extremities. Dino-Pull encourages arm extension, supination, and various types of crude and fine grasps.

Electronics and Data Acquisition: Audio/video feedback can be programmed. Play activity is recorded.

Figure.5 Magna Mitz

Students: Mary Davison, Mark Drew, Idil Ince

Toy Name: Magna-Mitz

Play: A pair of semi-rigid mitts embedded with powerful magnets. A non-magnetic table, two tabletop games (a magnetic crayon holder and a spinning glitter ball), as well as eight collection game pods, accompany the mitts. Snail Crayon leaves a crayon trail as it is moved with the mitts. The Glitter Ball game can be spun with movement of the mitts. The Collection Pods are a group play toy.

Rehabilitation Goals: Wearing the mitts induces wrist and finger extension. Both tabletop games encourage the child to exercise moderate upper extremity control while maintaining supination.

Electronics and Data Acquisition: Play activity can be recorded either on mitts or table.

2.5 Next Steps:

Midway through the semester we decided to apply for a grant in order to further the development of this concept. We applied for and won a **RHODE ISLAND RESEARCH ALLIANCE, RHODE ISLAND SCIENCE AND TECHNOLOGY COUNCIL (STAC)** Grant, which went into effect starting January of 2007. The following are excerpts from the grant proposal as prepared by Dr. Crisco:

2.6 Project Goals:

Brain injury, cerebral palsy and other neurological conditions create profound movement disorders in children, often leading to impaired use of the arm. Rehabilitation with physical therapy is critical for functional recovery. New rehabilitation techniques based on recent neuroscientific advances have been suggested to enhance recovery and to promote brain plasticity in patients following brain damage, however, these rehabilitation techniques have not focused on children nor have emerging methods, such as constraint induced therapy, capitalized upon the primary learning avenue for children playing.

Our overall goal is to design, develop and evaluate toys that are actually rehabilitation technologies designed to incorporate new upper extremity rehabilitation methods in a pediatric population and state of the art technology. In addition to their rehabilitative role these toy-based-technologies will record play activity data to allow clinicians and therapists to track the patient's progress and generate hypothesis driven evaluation of rehabilitation through objective, quantitative measures.

2.7 **Collaborations:**

This project will require a unique collaboration that will include Brown Medical School, Brown University, Rhode Islands Hospital, Meeting Street School, Afferent Corporation, Rhode Island School of Design, Bay Computer Associates, Inc. and Cornerstone Prototype Development Inc. Project administration, clinical support and patient recruitment will occur at Brown Medical School and Rhode Island Hospital. Afferent Corporation will provide expertise in clinical trials and pioneering neurotherapeutic medical devices to treat chronic neurological dysfunction. Afferent's lead technology enhances sensory function, which has been shown to be a key component in the recovery of brain function. These novel devices will be incorporated into the toys that interact directly with the child's arm. Rhode Island School of Design will continue their collaboration with the PIs to provide cutting-edge expertise in the design and fabrication of the toys. Bay Computer Associates, whose principal has worked with the PI for over a year, is a contract design firm that is experienced in the design of various electronics based systems ranging from consumer to FDA registered medical product.

3. Results and Discussions:

The team developed 2 racecar controllers for use with existing H scale electric racecar sets. One focuses on wrist extension and the other on pronation and supination of the forearm.

The Power-glove is a controller for radio-controlled cars and other toys. It uses a combination of wrist extension and pronation/supination.

The 4th toy is a heart-shaped computer switch that also combines wrist extension and pronation/supination to activate features within computer game and other software as well as small electric toys that have multiple features. The following are images that represent the process of research and development:

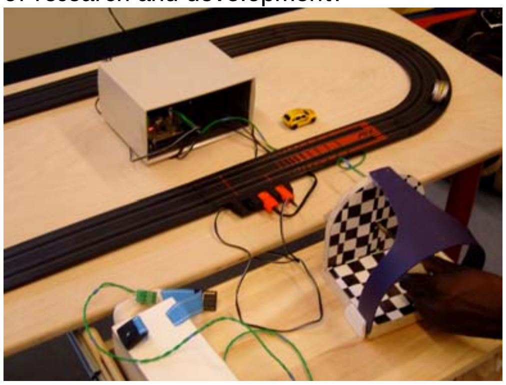

Figure.6 Racecar Controller Test Models

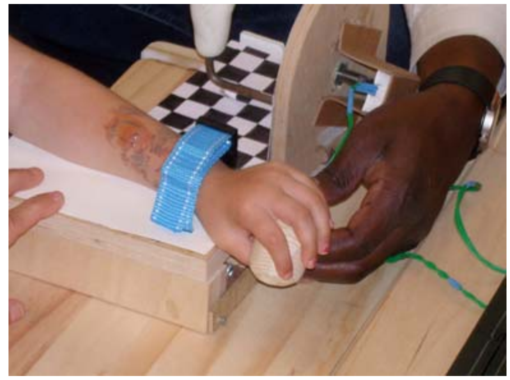

Figure.7 Wrist Extension Racecar Controller

Figure.8 Racecar Pronation/Supination Test

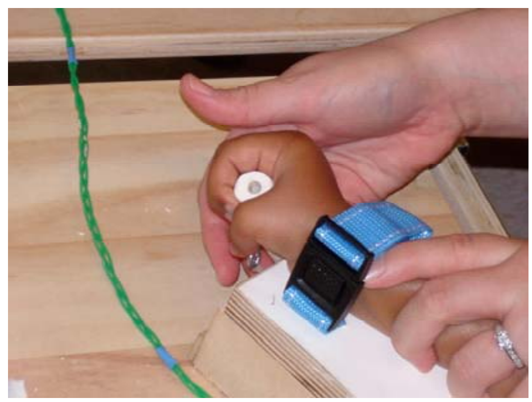

Figure.9 Wrist Extension Racecar Controller

Figure.10 Computer Switch Concept

Figure.11 Computer Switch Prototype

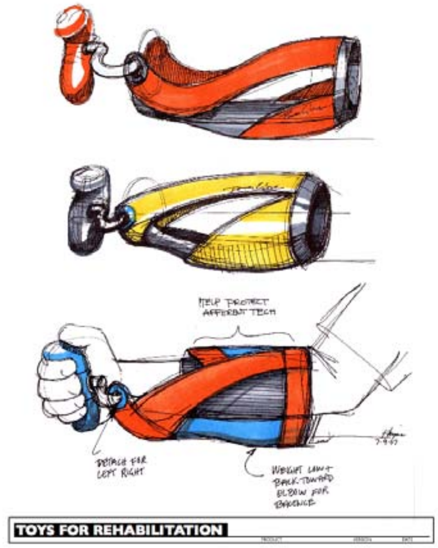

Figure.12 Power-Glove Concept

Figure.13 Power-Glove Prototype

Figure.14 Assembly of Racecar Controllers

Figure.15 Assembly of Power-Gloves

Figure.16 Presentation of Prototypes for Clinical Studies, June 2008

3.1. Project Summary:

Brown Engineering and RISD Industrial Design

During the Toys for Rehabilitation Studio in the fall of 2006, design methodology was used as the structure of the 12-week course. Prototyping was highlighted as a critical thinking skill, and used early in the process to resolve form issues and to test ideas. Quick sketch models were instrumental in communicating across disciplines and with our advisors.

During grant funded year- long development project the same methods of quick sketch modeling and prototyping were used within our development group, and with our venders. Solid-Works 3-D modeling software was used to communicate with Cornerstone PD who built 3 the sets of toys for the clinical study. We decided to have Cornerstone fabricate the parts and pieces of the racecar controllers and hire design students at RISD to assemble the toys. This approach allowed us to keep the fabrication costs within budget, while allowing students who were not in the original studio to participate and learn about the project and the process.

RISD ID Students also participated in the preliminary testing phase with CP children patients at Hasbro Children's Hospital, and CP students at the Meeting Street School. The preliminary tests were done using adjustable simple models designed to help us understand the children's strength, range of motion, size and orientation of the hand, and other factors effecting the direction of our design development. Our target user group were children with semi-palegic movement disorders of the upper extremities. We observed a wide range of abilities among the children within our age range of 5 to 12 and as a result we focused on adaptability and adjustability as primary characteristics for our toy designs.

4. CONCLUSIONS:

"The overall aim of this project is the development and evaluation of neurotherapeutic toys and related technologies," says Joseph "Trey" Crisco, Professor and Director, Bioengineering Laboratory Department of Orthopedics Brown Medical School/Rhode Island Hospital. "This initial clinical study under the direction of Dr. Karen Kerman is designed to evaluate the children's interaction with the toys, the technical capabilities of the toys and the toys' potential therapeutic benefit."

There was a great deal of satisfaction in moving a project from the classroom into the "real world" and being able to run the effort with the continued participation of students and interns from RISD, Brown University and Rhode Island Hospital. The use of quick 3-D visualization methods which worked so well in the studio class, proved to be invaluable when communicating between Cornerstone PD, Bay Computing, and the many therapists, the children with Cerebral Palsy, and our clinical advisors. The process made it possible to transcend the boundaries of the classroom and include multiple disciplines in state of the art research and development bringing within reach the great potential of serving an underserved population of children.

Also satisfying was the cooperation of the therapists and children at Hasbro Children's Hospital and The Meeting Street School. Interacting with the children directly had a great impact on the project, because we were able to see the light in their eyes when the products were having the desired effect, and the children were surprising their therapists by doing movement that were usually difficult, or avoided during their normal physical therapy sessions. The visualization methodologies used during the design process were a great benefit to the communication between disciplines, a principle which grew out of the original interdisciplinary Brown/?RISD design studio.

To Quote Dr. Trey Crisco:
"These are not your typical toys. With the thought that children use toys as a primary learning tool, the collaborators sought to help children with neurological conditions rehabilitate through high-tech toys.

The importance of this project is the development of revolutionary toys that enhance pediatric rehabilitation through play," Crisco says. "These toys are completely novel in their approach to enhance neuromuscular therapy and if proven to be successful would have a profound effect on the lives of these children in Rhode Island and across the nation."

5. Acknowledgements:

The success of the class and the project that followed would not have been possible without the generous efforts of the staff from Meeting Street School, Hasbro Children's' Hospital, Matt Cottam's students, and Northeast Orthotics and Prosthetics.

I would really like to thank the students, now alumni, whose hard creative work during the original design studio in fall 2006 served as inspiration for this project, and to the students and interns who contributed during the grant funded development process. I also want to acknowledge the remarkable collaborative work of Dave Durfee at Bay Computing, Dave Gaye at Cornerstone Prototype Development, and Susan E. D'Andrea, Ph.D.R&D Scientist.

This project would not have happened without the vision and support of Dr. Karen Kerman, and Dr. J.J. Trey Crisco, whose leadership and grant-writing skills are unsurpassed.