Chapter 8
NORTH CAROLINA STATE UNIVERSITY

College of Engineering
College of Agriculture and Life Sciences
Biological and Agricultural Engineering Department
D. S. Weaver Laboratories
Raleigh, North Carolina 27695-7625

Principal Investigators:

Susan M. Blanchard (919) 515-6726
Roger P. Rohrbach (919) 525-6763

OUTDOOR WHEELCHAIR SWING FOR TEENAGED CLIENTS

Designers: Wendy M. Lovelace, David S. Anderson
Client Coordinator: Jan Baker
Tammy Lynn Center for Developmental Disabilities, Raleigh, North Carolina
Supervising Professors: Dr. Susan M. Blanchard, Dr. Roger P. Rohrbach
Biological and Agricultural Engineering Department
North Carolina State University
Raleigh, NC 27695-7625

INTRODUCTION

Many of the older clients in a center for persons up to 18 years of age with developmental disabilities use wheelchairs. The center's existing wheelchair swing can accommodate only extremely small wheelchairs and fails to meet appropriate standards for day care licensing. A wheelchair swing that could accommodate a wide range of wheelchair sizes and styles and would comply with all standards for day care licensing was designed (Figures 8.1, 8.2).

Figure 8.1. Outdoor Wheelchair Swing.

SUMMARY OF IMPACT

Swinging is considered an excellent source of recreational therapy for people of all ages with disabilities. A playground swing for the user of a wheelchair can provide a safe and relaxing activity and can be rewarding for those who are capable of swinging themselves. Most wheelchair swings are designed for small children, but teen-agers in wheelchairs, especially those with developmental disabilities, can receive a great deal of pleasure from swinging outdoors.

TECHNICAL DESCRIPTION

The design involved locating an adequate restraint system, designing a sturdy swinging platform and loading ramp, developing a fail-safe backup system, completing an acceptable and sturdy frame, and minimizing the tasks of an assistant during loading. Extensive research for existing wheelchair restraint systems and wheelchair swings was conducted. Patent records, product literature, discussion with staff, standards documentation, and past National Science Foundation projects for persons with disabilities provided much information and direction.

A manufactured wheelchair restraint system for vehicles was chosen to secure the wheelchair because it is simple and safe, can be operated quickly, and because staff members are familiar with using such systems in their vans. The system secures the wheelchair with four polyester straps, which run around the wheelchair frame and snap into a steel ring. The opposite ends of the straps are clipped into custom restraint tracks welded to the platform floor. All straps are hand tightened and remain securely tensioned by a cam buckle. The straps are stored indoors when the swing is not in use, and can be replaced from the manufacturer when they become worn.

According to standards, loading ramps are required to have a slope of 1:12 or less. Due to this requirement and the size of the wheelchair platform, a 4-foot loading ramp was required. Hinging this ramp in the middle and again at the platform provides easy maneuverability. A front barrier along the loading ramp provides a fail-safe means to contain the wheelchair on the platform in the event that the restraint system should loosen during swinging. The front barrier, loading ramp, and platform are made from tread plated 6061-T6 aluminum. This material was chosen for its durability, high yield strength, and high strength-to-weight ratio features, which enable a long yet lightweight loading ramp. Also, the tread plate design adds traction for safe loading and unloading on a possibly wet or soiled ramp. Use of aluminum restraint tracks and hinges allows for strong and permanently welded connections. Side flanges two inches high were also welded onto the sides of the ramp and platform to add safety and rigidity. Lengths of treated wood cover the flanges so that the sharp metal edges are covered.

An inverted "V" style frame was chosen because of its stability and use of the least amount of materials. It is constructed of treated lumber because this is aesthetically pleasing, easy to work with, inexpensive, and very durable. All wooden edges are rounded to remove sharp and splintering edges, and the members are connected with galvanized lag screws.

A wooden extension was bolted to the top frame beam to attach a pull rope. This allows capable wheelchair clients to swing themselves by pulling on the rope during their forward swing. The swing platform is suspended by a combination of galvanized chain and "S" hooks with manufactured steel swing hangers at the top and steel anchor shackles at bottom. Similarly, the ramp and front barrier chains are attached to the main swing chains by spring snap links at the top and quick links at the bottom. All chains are covered by vinyl tubing to eliminate pinch points as required by day care licensing standards.

Figure 8.2. Ramp in Extended Position.

The completed outdoor wheelchair swing meets all required standards and is currently being used by wheelchair clients. The ramp is lowered to allow easy loading of a wheelchair. The wheelchair is secured with the 4 restraint straps and the ramp and front barrier are raised to achieve a safe swinging position. An assistant may swing the wheelchair manually. If the occupant is capable, he or she may propel the swing by using the pull rope.

The total cost for this project, not including labor, was approximately $700.

PORTABLE PADDED CHAIR FOR CHILDREN

Designers: Michael Wade, Christopher Ehrhardt
Client Coordinator: Beth Buck
Tammy Lynn Center for Developmental Disabilities, Raleigh, North Carolina
Supervising Professors: Dr. Susan Blanchard, Dr. Roger P. Rohrbach
Biological and Agricultural Engineering Department
North Carolina State University
Raleigh, North Carolina 27695-7625

INTRODUCTION

The staff at a center for children with developmental disabilities requested a chair to provide posture support needed by children, ages birth to three years. This chair was to be lightweight and portable, while having adjustable padding devices and a tray (Figures 8.3, 8.4).

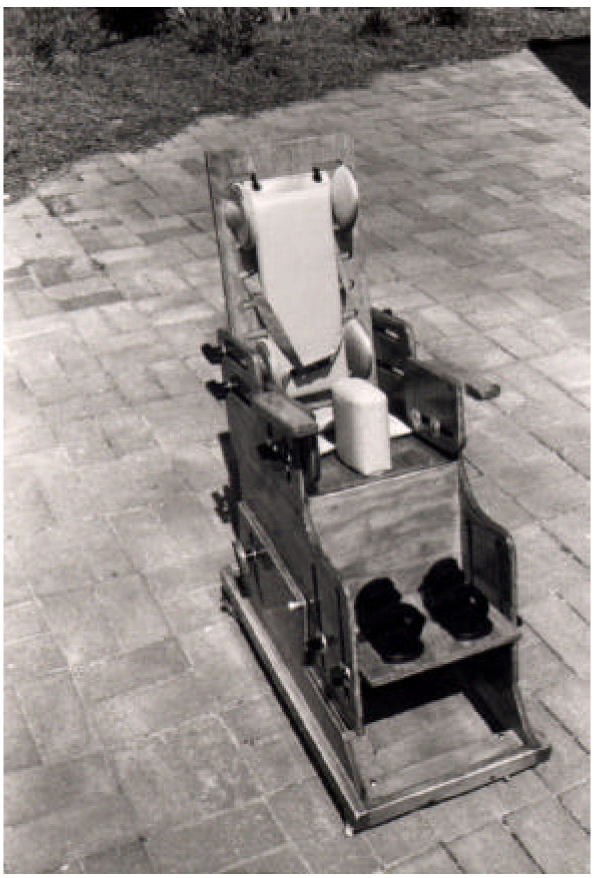

Figure 8.3. Portable Padded Chair.

SUMMARY OF IMPACT

The children for whom the chair was designed greatly needed a chair that would provide proper posture support and a feeling of comfort and safety. While the chairs currently available individually provided one of these aspects, there were none that met all the needs of the staff and children.

For a child with developmental disabilities, being comfortable while sitting in a chair can be a great challenge. Much of the child's energy and focus are consumed by just trying to get comfortable. The advantage of this chair is that it provides comfort, such that the child is more relaxed and able to focus on play or other activities.

TECHNICAL DESCRIPTION

The design involved developing a chair that would fit children, ranging in age from birth to three years. This meant that the chair needed an adjustable headrest, footrest, backrest, armrest, and padded supports. Patent documents, product literature, ergonomic data, and staff members were useful sources for this information.

The padding, supports, and foot restraint chosen for this chair were purchased through a commercial catalog, as they needed to meet specifications established by the center. These specifications included ease of cleaning, adequate support and comfort, and aesthetic appeal. Purchasing this padding from a commercial dealer allowed for the exact sizes necessary for the chair. The seat and back padding were simply tied to the frame of the chair. The head and support pads were attached using clamping knobs. This allowed for easy adjustment of the head and support pads.

Selecting material for the chair was a difficult task. It was necessary to choose a material that would not only be strong and durable, but also aesthetically pleasing. Plywood was used for the main construction of the chair. This material was easily available, durable, and, when sanded and stained, aesthetically pleasing. Another specification for the chair was that it could be moved or kept stationary. To fulfill this need, lockable casters were attached to the chair frame. The casters allowed the chair to roll freely and, when necessary, to be locked in place to secure the child.

The backrest was designed to move forward 3-1/2 inches. This created a seat depth range with a maximum of 11 inches and a minimum of 7-1/2 inches. The armrest was built to adjust upwards as well as forwards. The armrest can be raised 1-1/2 inches and moved forward 2 inches. A minimum distance of 4 inches from the seat can be achieved by adjusting the footrest from its maximum distance of 10 inches. The head rest and side supports were created to adjust to a maximum spacing of 7 inches and a minimum spacing of 4 inches between supports. By using slots in the side of the frame, the chair can be tilted backward to a 45-degree angle.

The total cost for this project, not including labor, was approximately $260.

Figure 8.4. Padded Portable Chair with Tray in Place.

DOUBLE STROLLER FOR AN ABLE-BODIED AND A DISABLED CHILD

Designers: Heidi Lane, Robert Schoderbek
Client Coordinator: Beth Buch,
Tammy Lynn Center for Developmental Disabilities, Raleigh, North Carolina
Supervising Professors: Dr. Susan Blanchard, Dr. Roger P. Rohrbach
Biological and Agricultural Engineering Department
North Carolina State University
Raleigh, NC 27695

INTRODUCTION

Staff members at a center for children with developmental disabilities requested a double stroller that could accommodate a child with a disability and an infant for use by families involved with the center. There are no existing strollers on the market that meet the needs of some families. Available adaptive strollers tend to be much larger than normal strollers and yet only hold one child with a disability. Existing normal strollers provide no head or hip support for children with disabilities. The double stroller provides support for the child with disabilities and more like a general-use stroller than an adaptive one.

SUMMARY OF IMPACT

Strollers facilitate the activities of a family with multiple children and are especially useful if one or both of the children cannot walk. A stroller that can hold an able-bodied infant or toddler and an older child with a disability provides the means for easier movement and allows both children to participate in outings.

TECHNICAL DESCRIPTION

The design of the double stroller involved researching information on existing strollers, and designing a sturdy frame, a seat that provides adequate support for the child with a disability, a foot rest for the adaptive seat, and a normal seat.

The first step was to gain as much knowledge as possible about existing products and the needs of disabled children. Patent documents, the center staff, and literature on safety hazards provided information needed for this design project. Because of its high strength and low deformation characteristics, steel was used in the construction of the frame. The wheels were ordered from Graco, Inc., and the pieces that the wheels slide into were donated.

Figure 8.5. Double Stroller.

The adaptive child's seat provides the client with three different positions for harnesses and head support. Both the head and hip supports have different sized padding that can be attached simply by pressing Velcro strips together. This allows for varying amounts of support, depending on the need and size of the child in the adaptive seat. There are also straps for the adaptive footrest. Both the head and hip support systems can be removed by the user if needed.

The completed double stroller tested positively for its ability to hold 50 pounds in each seat using the Standard Consumer Safety Performance Specification for Carriages and Strollers. The stroller was also tested for its rolling resistance, which was less than 0.1, indicating that little effort is required to push it.

The cost of construction is approximately $257. This includes all metal components, fabric, paint, and miscellaneous hardware. The cost is within the range of non-adaptive double strollers presently on the market, and far less than most adaptive strollers.

Figure 8.6. A Client Tries out the Double Stroller while the Designers Look Onward.

SWITCH ACTIVATED SWING FOR CHILDREN UP TO 50 POUNDS

Designers: Tiwanna N. Bazemore and Addie E. Dillon
Client Coordinator: Beth Buch
Tammy Lynn Center for Developmental Disabilities, Raleigh, North Carolina
Supervising Professors: Dr. Susan M. Blanchard, Dr. Roger P. Rohrbach, Dr. Gerald Baughman
Department of Biological and Agricultural Engineering
North Carolina State University,
Raleigh, North Carolina 27695-7625

INTRODUCTION

A modified infant swing was requested for use at a center for children with developmental disabilities. It was intended to hold, support and swing a child who weighing up to 50 pounds. Existing infant swings are not sturdy or powerful enough to safely swing a 50-pound child, and current swing seat models of do not offer enough head or torso support for a child who lacks sufficient muscle control. In addition, sterility of the seat is an important factor overlooked by many manufacturers. Through meetings with consultants at the center, the specifications required to meet safety needs were established. Further consultation with university engineers facilitated the generation of design ideas for altering the swinging mechanism and frame of a typical infant swing.

The chosen design consists of an offset crank and motor to drive the swing, and a wooden A-frame to support the swinging child (Figures 8.7, 8.8). The seat is a contoured, supportive feeder seat with a modified PVC pipe frame to secure the seat to the chains. It has proper chest and head restraints. The seat is easy to clean and maintain. It is also adaptable for use with an outdoor swing set.

SUMMARY OF IMPACT

Infants enjoy swinging from a very early age, and many types of wind-up swing are available for able-bodied infants up to 25 pounds in weight. Small children with developmental disabilities also enjoy swinging, but often are not capable of swinging themselves, nor small enough to use existing infant swings safely. External stimulation, such as swinging, is relaxing and recreational. A motorized swing set for a small child would provide entertainment for many children with disabilities.

Figure 8.7. Switch-Activated Swing.

TECHNICAL DESCRIPTION

The overall dimensions of the swing design were determined by the body size of 95% of 50-pound children. The height of the swing is 68 inches and the width 48 inches. The depth of the base is 56 inches to prevent tipping during swing motion. A 5 by 6 foot area is the minimum space desired for safe operation.

The frame of the swing is an A-frame made out of douglas fir wood. The top member is a 4-by-4, which supports the suspended driving mechanism. The legs are each 2-by-4s and are attached to the top member by sturdy sawhorse brackets. Each bracket contains a wedge and a 3/8-inch carriage bolt to hold the members together. The legs are braced with a swinging aluminum bar on each side, which is permanently attached to one leg and swings up to latch on the opposite leg, providing sufficient lateral support. This frame design allows for simple disassembly involving (unlatching the cross bars and removing the two carriage bolts in the sawhorse brackets).

The driving mechanism consists of a 30 RPM, 1/10 horsepower shaded-pole motor attached to a pulley system, which is attached to an offset crank. Figure 8.8 shows a close-up view of the driving mechanism, with the motor-pulley system connection, the offset crank, supporting bearings, and the housing unit for the pulley system.

The pulley system allows for fine-tuning of the motor speed to match the natural frequency of the swing. The pulley is covered by a plastic housing unit to prevent injury. The motor-pulley system provides the appropriate rotation speed for the offset crank, which is threaded through vertical slots of two oblong rings suspended from the top of the frame by swing hangers. The top points of the rings serve as the pivot points of the pendulum arm, and the bottom portions of the rings are free to move with the circular motion of the offset crank. The chains are attached to the bottom portions of the rings. The rings catch the horizontal components of the circular motion of the offset crank that translates into the appropriate swinging motion.

The most important factor in selecting a seat was the support it provided for a child. Existing swing seats were not satisfactory to the client, so alternative options were explored. A feeder seat was considered because it offers hip and torso support and also has a bolster to keep the child from slipping. An additional chest harness and lateral head support are used in conjunction with the feeder seat to offer optimal support. The plastic seat material and supports are washable and waterproof. The swing can be used outdoors if necessary.

A PVC piping cradle was designed to snugly hold the seat, and nylon strapping threaded through the harness slots of the seat provides secure attachment to the PVC cradle. The seat cradle is suspended by 2/0 Inco double loop chains, which are ideal for swings and playground equipment. The working load limit for these chains is 255 pounds, which is more than adequate for this swing. Two chains connect to the front sides of the seat cradle to the suspended rings. The backsides of the cradle have two short chains that hook into the full-length chains, forming triangles. The lower portions of the chains are covered with PVC piping to meet day care safety standards and to prevent tipping of the seat.

The total cost of the swing and seat was approximately $740. This included $385 for the feeder seat and supporting harness.

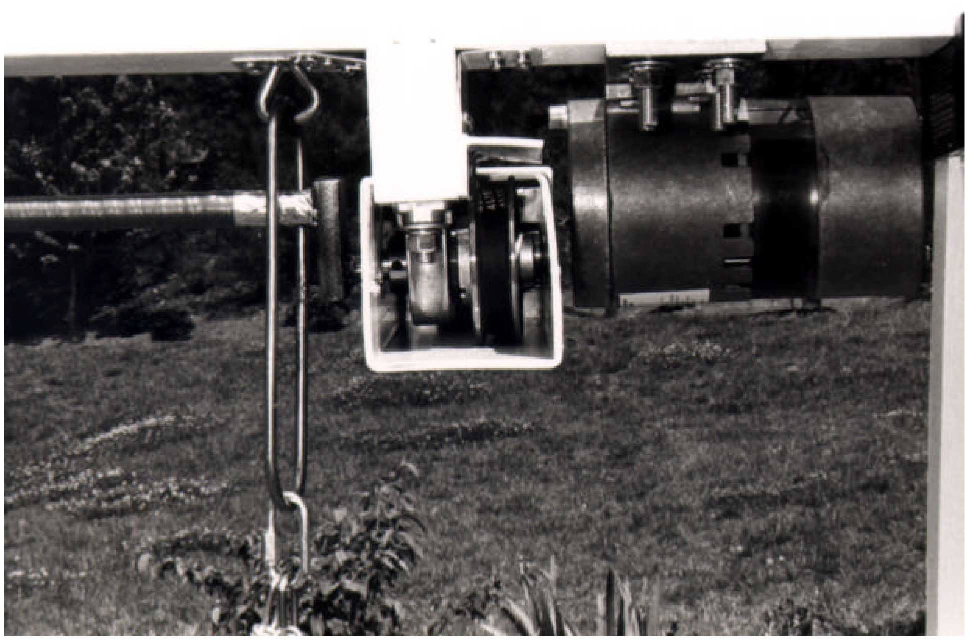

Figure 8.8. Driving Mechanism for the Swing.

SPEAKING SCHEDULE BOARD

Designers: David Chilton, Jason Geddes, Eric Kelly
Client Coordinator: Anna Troutman
Tammy Lynn Center for Developmental Disabilities, Raleigh, North Carolina
Supervising Professor: Dr. William D. Allen
Department of Electrical and Computer Engineering
North Carolina State University
Raleigh, NC 27695-7911

INTRODUCTION

The speaking Schedule Board is an interactive modular system for organizing daily schedules. It sequentially announces a series of tasks or activities to its user. The system consists of a control module and up to 10 response modules (Figure 8.9). The control module determines the overall sequencing of tasks. Each response module contains an independent voice record-store-playback unit. Audio announcements of tasks are programmed into the response modules and the schedule is arranged by the order in which the units are plugged together. The module containing each subsequent announcement lights an indicator. When the user presses the large task button, the announcement is played. Once an announcement has been played, the system progresses, after a delay, to the next module in the series. The system modules are light and compact, making the device usable at school and at home. This system represents a significant advancement over a rudimentary voice announcement system previously used by the client.

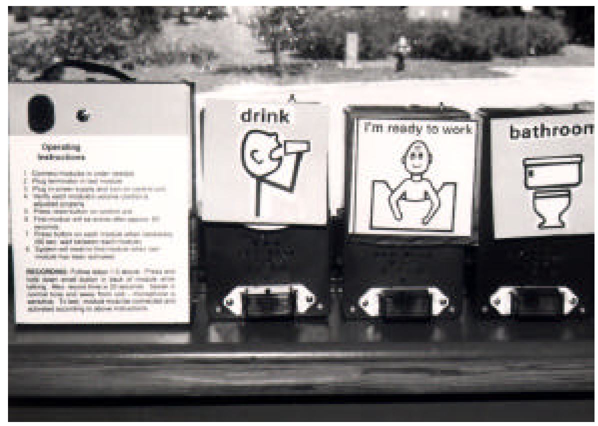

Figure 8.9. Speaking Schedule Board.

SUMMARY OF IMPACT

The Speaking Schedule Board was designed for a student with multiple disabilities. She is non-verbal and non-ambulatory. To facilitate her development, her instructors want her to have an interactive tool for implementing her daily schedule. Prior to using this system, she was using picture frames that included a feature for recording and playing short messages. However, their sound quality is poor, and the playback button is too small for the client to use. Additionally, the frames do not present a visual indication of which task the client is to accomplish next. The newly designed system is modular, allowing the instructors to configure as many tasks (up to 10) as they wish to schedule. The voice recording and playback circuits represent a significant improvement over previous devices. Physically, the modules incorporate large, sensitive, lighted push buttons that are easy for the client to use. Since the system automatically sequences the assigned tasks, she has become more interactive with her daily scheduling. The client's mother, and the residential and instructional staff of the center for developmental disabilities the client attends, report that they are very pleased with the system. Although this device was specifically designed for a specific student's needs, it would be useful for any individual requiring structured scheduling cues. Similar but less sophisticated devices have been developed to provide both scheduling cues and aural stimulation.

TECHNICAL DESCRIPTION

The main design requirements for this system were that it 1) be lightweight, 2) provide visual, tactile, and auditory stimuli, 3) allow easily programmed voice output, and 4) provide easy rearrangement and reuse of schedule elements. From these requirements, a modular system was developed, comprised of a master control unit and several response units that may be plugged together (Figure 8.10). The modularity of this system allows the number of tasks in the sequence to be varied (up to 10), and the order of tasks rearranged without re-recording task announcements. The master control unit serves three functions by providing:

1) DC power to the remaining modules, 2) a delay timer for sequencing tasks, and 3) task sequencing to the chain of attached response modules. The two 4-bit address buses from the control module, passed from module to module, are the key to enabling task sequencing to be determined simply by the order in which the modules are plugged together. One bus (ADDR) always exits the base unit with a value of zero. Each module in the chain adds one to the value before passing it on to the next module. Thus, each module sees a unique address value on the ADDR bus. The second bus (ADDRESS) is passed unchanged through the entire series of modules. When the control module initializes, it sets the value of the ADDRESS bus to zero. Whenever a response module is activated, the control module starts a 60 second timer. When the timer expires, the control module increments the value on the ADDRESS bus. This delay allows multiple activations of the task switch so the message may be repeated before the system advances to the next response module. At the end of the chain of response modules, a termination plug routes the ADDR bus back to the control module as the TERMINATOR bus. When a comparator in the control module finds the ADDRESS bus equal to the TERMINATOR bus, a reset signal is generated. This reinitializes the control module so it will begin sequencing through the series of response modules again. Each response unit contains its own voice record-store-playback circuit. Visible on the exterior of each response module are the task switch, next task light, record button, microphone, volume control, and speaker. Internal to the response module is the digital voice record circuit, audio amplifier, and supporting logic. Each response module compares the values on the ADDR and ADDRESS buses and, when it finds them to be equal, enables itself. The combination of the position dependent ADDR value and the generated ADDRESS value from the control module serve to sequence the activation of each response module. Whenever a response module is enabled, its indicating light will be illuminated. This directs the user as to which button to press next. If a task button is pressed on a response module that is not enabled, the button press is ignored by the system. The system is powered by commercial AC power. Thus, while the system is portable, it is not mobile. Power is converted in the control module to low voltage DC, which is transferred through the module connectors. Construction costs were approximately $1,855. While each module was not exceedingly expensive on its own, the large number of response modules (10) built, along with the single control module, increased the total system cost. A system using a common audio amplifier and speaker housed in the control module would be less expensive. Using a multimessage record-store-playback device may also be less expensive, but would result in less flexibility for rearranging the schedule.

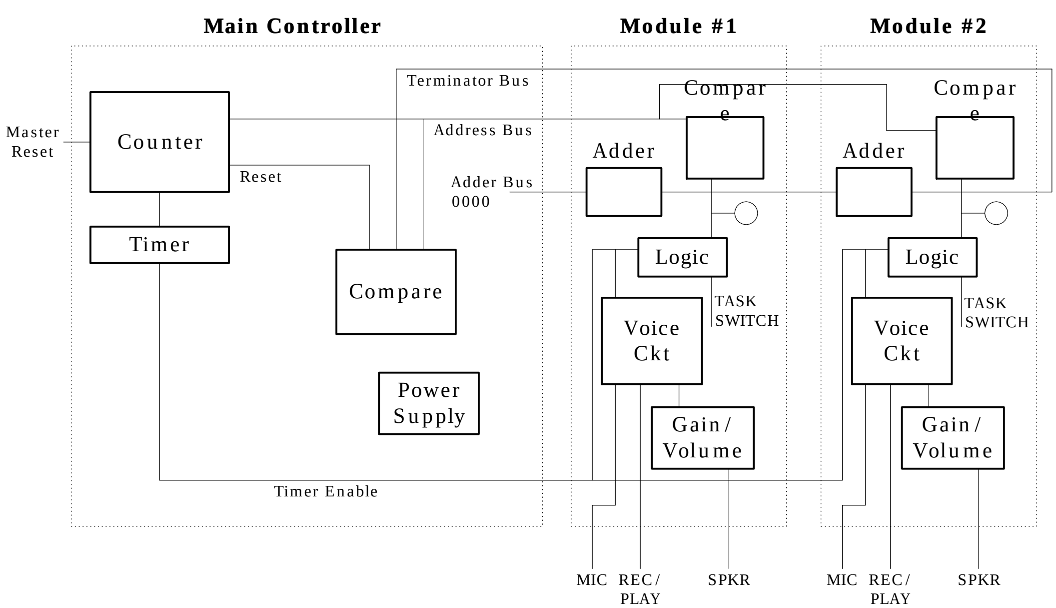

Figure 8.10. Speaking Schedule Board.

TALKING COMMUNICATIONS BOARD

Designers: Christopher Dawson, Cerine Hill, Maya Purrington
Client Coordinator: Anna Troutman
Tammy Lynn Center for Developmental Disabilities, Raleigh, North Carolina
Supervising Professor: Dr. William D. Allen
Department of Electrical and Computer Engineering
North Carolina State University
Raleigh, NC 27695-7911

INTRODUCTION

The Talking Communications Board plays prerecorded voice messages associated with physical objects pulled off the board. It was designed to address the communication abilities of a specific student at a center for children with developmental disabilities. The board operates by allowing the caregiver to record up to ten different messages. For each message, there is a position where an object, attached by Velcro, can be pulled away from the board. This action triggers the playback of the recorded message. The concept was taken from a preexisting (non-speaking) board being used by the student. The new board is large enough to hold ten objects yet is still portable (Figure 8.11). The device is battery powered, so the unit is completely mobile. The recorded messages are readily changeable by the student's teachers and family members.

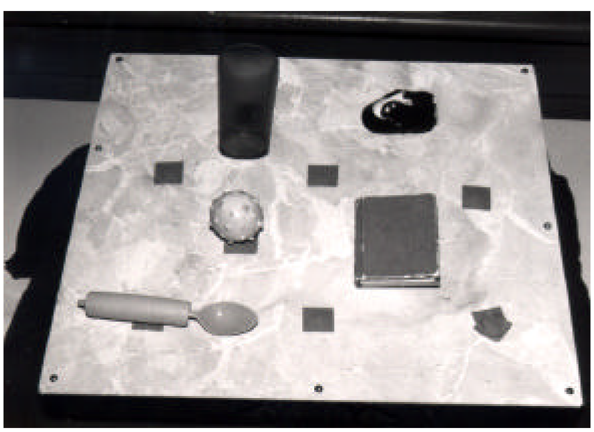

Figure 8.11. Talking Communications Board.

SUMMARY OF IMPACT

The Talking Communications Board was designed for a 12-year-old boy who is blind and severely retarded, with severely limited communication abilities. His only method of communication is through the use of a "vocabulary" of 30 physical objects attached to a board by Velcro tabs. When presented the board, he "speaks" by removing objects. For example, if he removes a cup, this means that he is thirsty. If he removes a baby shoe, this means he would like to go for a walk. Prior to receiving the current device, the student used a board with attached objects. However, that board had only two positions. The goals of this project were to increase the number of objects on the board and add a voice response to the removal an object. Addition of the voice messages allow him to communicate with people who do not know his vocabulary of objects, draw more attention to his needs, and facilitate learning of new vocabulary through increased verbal feedback. Although designed for a specific individual, this device would also be useful for anyone with speech, cognitive, and/or visual impairments. For example, some patients with Alzheimer's disease may communicate with objects in a similar fashion; adding the audible messages would yield similar benefits. This project may also be useful for normally developing children. It can be used to teach toddlers vocabulary in a more tactile way than a "See-and-Say". The configurability of objects and messages provide flexibility not afforded by more structured devices.

TECHNICAL DESCRIPTION

The main design requirements of the board were that it: 1) accommodate a reasonable number of objects, 2) provide voice response upon removal of an object, and 3) be portable. A block diagram of the system is shown in Figure 8.12.

An initial prototype board, without electronics, was developed to determine the physical dimensions and number of objects the student could tolerate. The prototype was 14 by 16 inches, large enough to hold up to 10 objects yet small enough to be portable. After a one-week trial, a clinician determined that the final device should be designed for 10 objects, and that its dimensions should be 17 inches wide by 15 inches deep with a thickness tapering from 4 inches at the rear to 1 inch at the front. Several types of sensors were considered for detecting the removal of an object. Magnetic switches were selected, as they were inexpensive, insensitive to ambient conditions (e.g., light), and not dependent on a significant degree of motor skill. The magnetic switches are embedded in the top of the unit and covered with a Velcro mating patch. The objects have a flat rare-earth magnet attached under the mating Velcro patch. The magnets are strong enough to actuate the switches through the Velcro, but not strong enough to affect adjacent switches. An ISD 2590-voice chip handles the recording, storage and playback of the voice messages. This integrated circuit device can store 90 seconds of audio data in fully addressable, non-volatile memory. It easily switches between play and record modes, has a built-in microphone preamplifier and speaker amplifier, and has an "end of message" signal that is used to place the system in a power-conserving standby mode. The microphone is embedded in the rear of the case along with all control switches. A speaker is installed in the left side of the case. The volume from the voice chip is adequate for areas with normal ambient noise levels. An audio output jack is also available so the board could be connected to an external amplified speaker if needed. Control and sequencing requirements of the system include: 1) detecting removal of an object, 2) determining when to record a message, 3) selecting modes (record, play, standby), and 4) addressing the voice chip for the selected message to play/record. The digital control logic was implemented using a Xilinx 3020L Field Programmable Gate Array (FPGA). This FPGA is reprogrammable so that minor functional changes in the operation of the system can be implemented without major rewiring. The only other logic elements needed were a 555-timer device to generate a system clock and a serial PROM to store the FPGA configuration data for power-up initialization. Four D-cell batteries supply power for the system. Smaller batteries would work as well but would not last as long as the D-cells selected The system power is regulated to 5 volts DC so either rechargeable or non-rechargeable batteries can be used. No provision was made for recharging the batteries in the system. The batteries are housed in a small drawer in the right side of the case. Construction of the Talking Communication Board is relatively inexpensive. The case was fabricated from wood and Plexiglas. The design uses relatively few components, none of which are expensive. The total cost of the parts needed to construct the system was approximately $177.

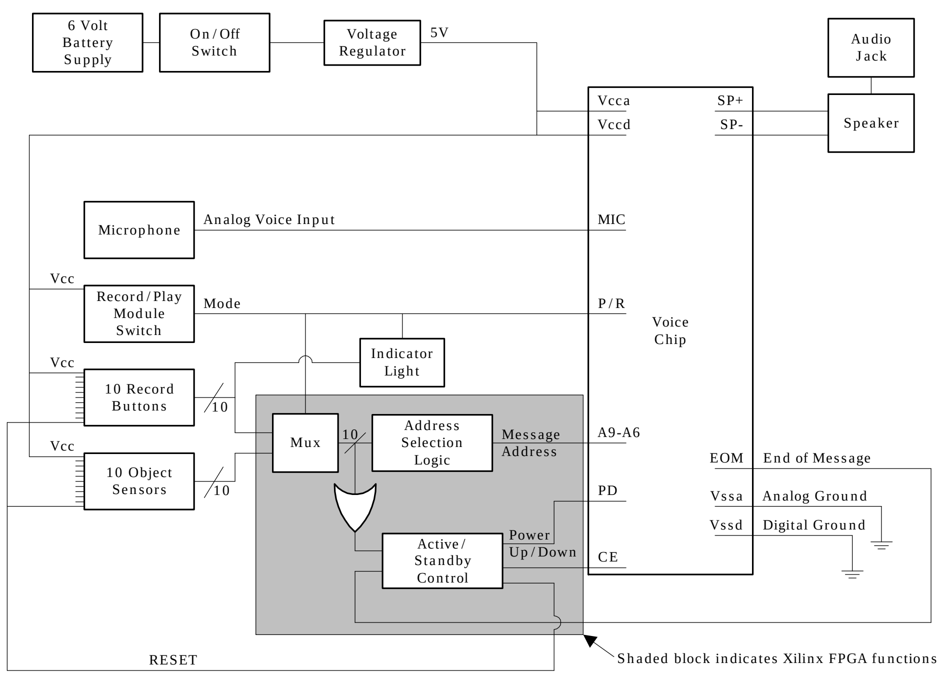

Figure 8.12. Talking Communications Board.