CHAPTER 18
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Redesign of a Mechanical Wheelchair Mounting for a Communication Device

Designers: Amy Neidhard, Alicia Woyton
Client Coordinators: Wilma Blair
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INTRODUCTION

The project concentrated on a Gorman Public School student who is inflicted with a severe case of spastic cerebral palsy. The young girl, named Courtney Gill, has very limited hand coordination and experiences swaying head motions. A Liberator augmentative communication device, by the Prentke Romich Company, has been implemented for Courtney's use in learning speech. The Liberator board is divided into numerous squares, each of which contains a red light-emitting diode (LED) that blinks at a constant frequency. A photodetector is equipped with a filter that is only sensitive to red light, and is mounted to the frame of a pair of eyeglasses. If the photosensor is positioned over a square on the Liberator board for four to five seconds, the sensor registers the red light emitting from the blinking diode within the selected square. Utilizing feedback control, the word or phrase represented by the selected icon is then spoken by the Liberator device. The Liberator's voice is the only vehicle for Courtney's verbal communication.

The Liberator was previously supported by a mounting system that attached directly to the wheelchair. Unfortunately, the mount was difficult and unreliable to position in front of Courtney, and frequently collapsed due to the instability of a single friction joint. With this mount, the unpredictable and involuntary movements that Courtney experiences prevented her access to the full range of the communication board, and its single piece construction prohibited any further adaptations to Courtney's small size. The mount was not adjustable in height, requiring that additional mounts be purchased as Courtney grew, and hindered her from mastering effective augmentative communication. It additionally endangered the safety of the child in the event that the communication device fell during the structure's collapse.

It was proposed by the Gorman School teacher that a new mount for the communication device be designed with emphasis on stability, adjustability, and the capability of locking the board in place at Courtney's eye level. The purpose was to greatly improve Courtney's ability to functionally employ the Liberator device. The new support system is completely adjustable, allowing both room for Courtney to grow and the precise positioning of the communication device.

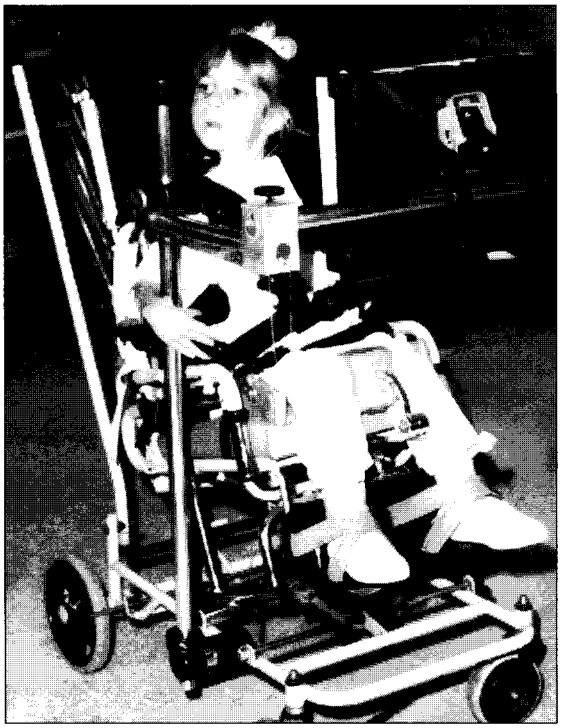

Figure 18.1. Designed Support System Locked Into Wheelchair.

SUMMARY OF IMPACT

The new support structure enabled Courtney to communicate more effectively with her teachers and family, despite her severe speech impairment. In addition, Courtney's learning potential was substantially improved. The facilitation of the Liberator's positioning eliminated the frustration that visibly overcame Courtney as she attempted to access the Liberator with the previous system's mount. Increased productivity in communication is an asset to the disabled individual since it augments their otherwise dampened independence. Courtney's teacher and parents commended the improved efficiency of Courtney's icon selections and the convenience of the rotator assembly, enabling the Liberator to be oriented without the physical assistance of an additional individual.

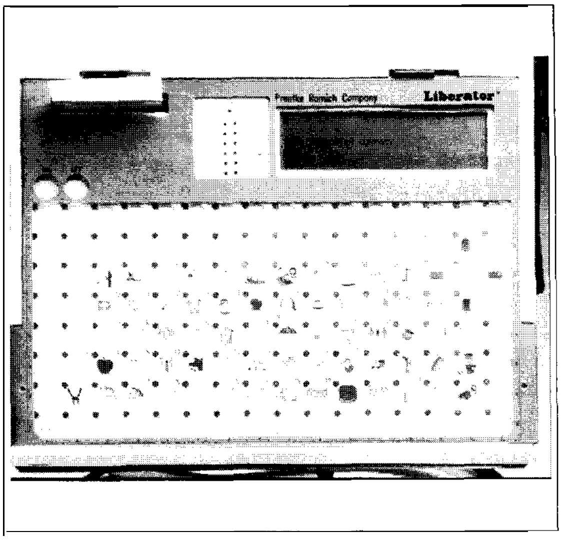

Figure 18.2. Liberator Augmentative Communication Device.

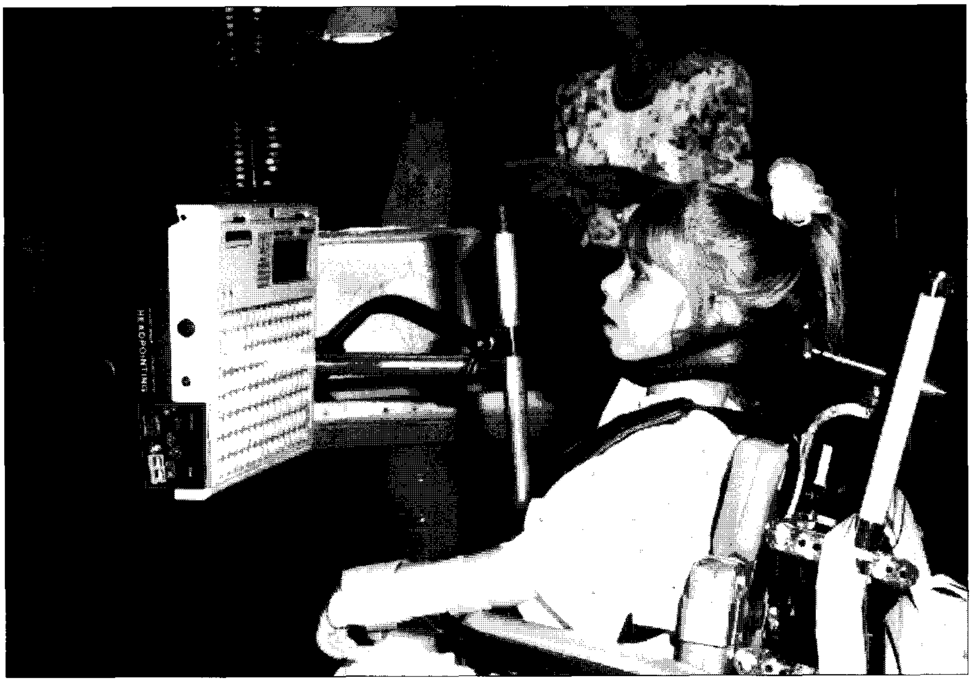

Figure 18.3. Liberator Positioned Directly Before Courtney.

TECHNICAL DESCRIPTION

The designed support for the communication device can be moved in three directions of translation; along the x-, y-, and z-axes, and angularly. The metal mounting can be adjusted vertically, up and down, and horizontally, to the right or left of Courtney's head, so that the Liberator board can be stably positioned directly in front of Courtney's face, at eye level. The depth of the Liberator is also adjustable. The communication board itself, can be tilted toward and away from Courtney so that the best angle between the photosensor and the board target can be achieved. The mounted Liberator board can be swung into and out of position in front of Courtney, both manually, while attached to the base of the wheelchair, and remotely, when placed into a rotator assembly. In addition, the mounting system can be collapsed to a folded position beside the wheelchair when not in use.

The support structure consists of a 35” long vertical member, and two horizontal members, 13” and 19” in length, representing width and depth, respectively. All members are composed of 1" diameter polished aluminum rod and are orthogonal to each other. Care was taken in choosing the composite material for the members to maintain a lightweight system, while ensuring that the material is strong enough to support the weight of the Liberator device and any extraneously applied bending moments. The adjustment of the height, width, depth, and tilt angle of the support system are achievable through the implementation of two crossover joints at the intersection of two members. This type of joint allows motion in two perpendicular directions at the same point in space.

The joint at the intersection of the width and depth horizontal members consists of an aluminum block with two 1” holes bored and broached to allow insertion of the aluminum rods at right angles. The Liberator is attached to the horizontal width rod during Courtney's use. A $\frac{1}{4}$ inch slot was machined into each of the horizontal rods and a $\frac{1}{4}$ inch metal key was slip-fit into the groove of the rod and the broach of the joint, as the rod was inserted into the joint. The purpose of the key was to assume any applied torques of the mounting system, preventing the rotation of the members within the joint. The desired position can be locked into place by tightening a handled-hex screw onto the key that rests within the metal rod. The dual-handle joint at the intersection of the horizontal depth and vertical members was purchased and features a double swivel action. The horizontal member was secured with epoxy and a bolt to one 1” orifice of the swivel joint, to prevent rotation upon applied torques. By loosening the respective handle that adjusts depth, the support assembly can be positioned angularly or collapsed into a folded position beside the wheelchair. The vertical member was inserted within the remaining 1 inch orifice and the respective joint handle can be loosened or tightened to adjust or lock the desired position, respectively. The system locks into the frame of the wheelchair. Each adjustment that is made by positioning a rod within a joint orifice is strictly independent.

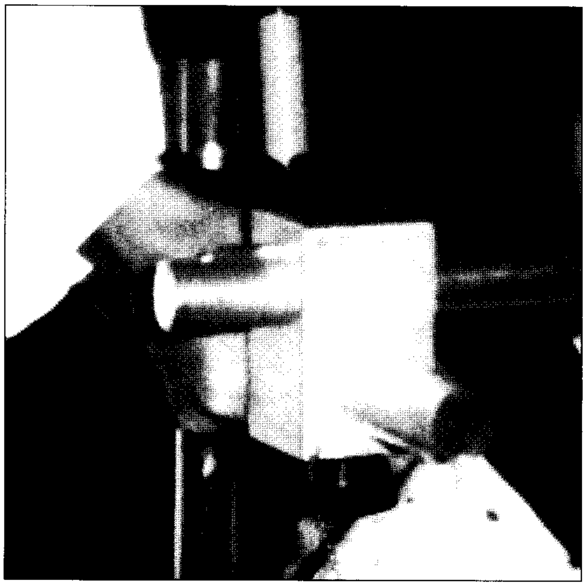

Figure 18.4. Enlarged View of Crossover Joint.

The entire support structure can be removed from the wheelchair and locked into a separate rotator assembly. An adapter was machined to enable the support structure to be interchanged between the wheelchair and the rotator.

The rotator enables the teacher to move the Liberator in front of Courtney by remote control, thereby eliminating the assistance of another individual during Speech class, when the device is most often used. The rotator assembly was incorporated from an antenna rotator and mounted to a 16” diameter circular, concrete base. The base was equipped with locking casters for easy mobility and painted for durability. Plastic endcaps were fixed to any exposed metal edges to prevent injury.

The design provides six independent adjustments of the support structure, allowing the Liberator to be accurately positioned before Courtney, or another individual. Its adaptability enabled Courtney to more effectively communicate and participate in classroom activities. The final cost for the development of the mechanical wheelchair mounting and rotator assembly is $705.

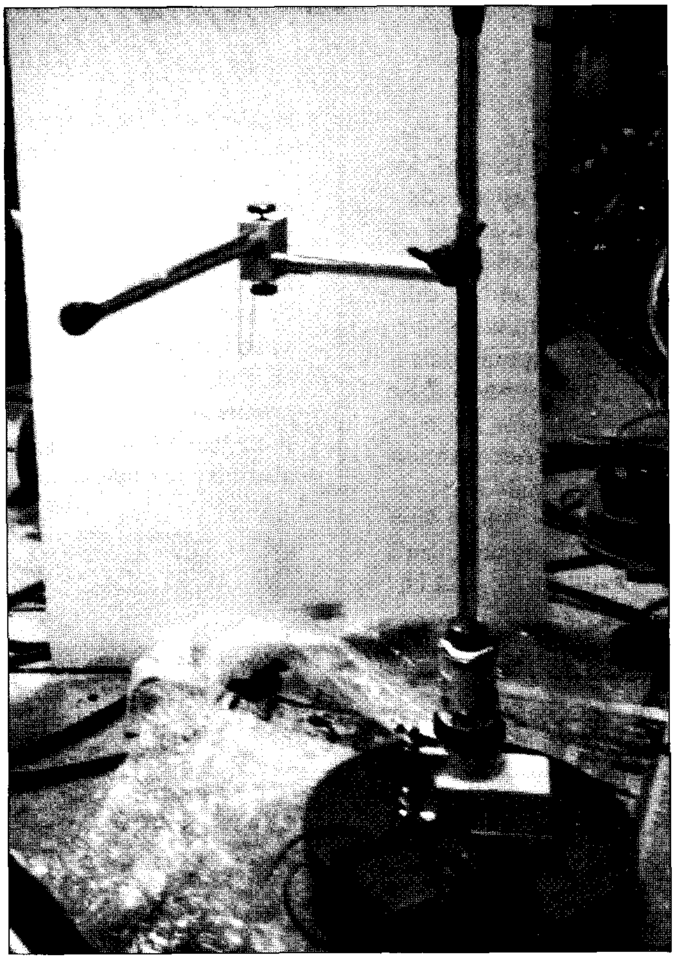

Figure 18.5. Support System Locked Into Rotator Assembly.

ABC: Audio Box Communicator

Designers: Moneer Abdulwahid, Nedal Abushanab, Brian Marriott
Client Coordinators: Linda Comer
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INTRODUCTION

A portable electrical communication device was designed for a classroom of young handicapped children at Gorman Public School between the ages of eight and eleven. The students suffer from physical symptoms of poor muscle tone, control, and coordination as well as comprehension, speech, and hearing impairments that are typical of cerebral palsy. As a result, the children are severely limited in their ability to learn, communicate with others through speech or written words, and control the confined physical abilities that they do have, despite their often normal level of intelligence. The Audio Box Communicator was designed to assist the children's communication through a partitioned, switch-activated device with compartments to place objects that the children can select in response to a teacher's question. Positive feedback for correct responses occurs in the form of a light and a pleasant sound or spoken phrase of encouragement. The children will learn that the correct response yields a reward.

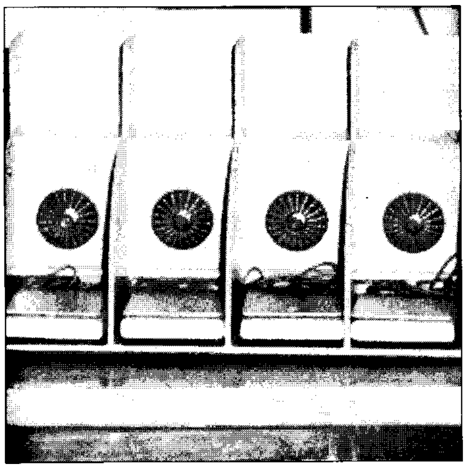

Figure 18.6. Front View of ABC with Switches intact.

The partitions prevent students from pressing more than one switch at a time and guide the hands of students without fine muscle control. Removable switches enable the most physically limited child, with the smallest range of motion, to use the device. There are a large number of compartmentalized communicators currently available on the market, but none which have speech capabilities or the option of turning off individual compartments to prevent feedback for incorrect responses. The purpose of the Audio Box Communicator is to provide a means of communication between the students and their teacher through implementing both visual and auditory feedback.

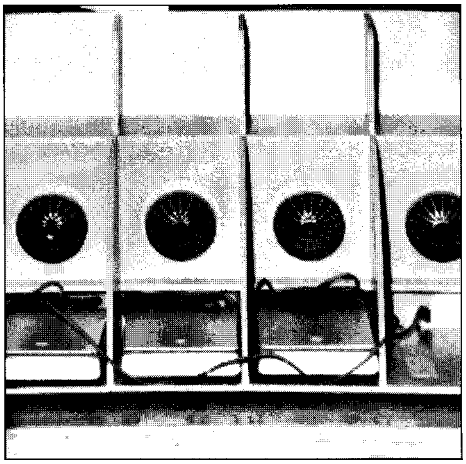

Figure 18.7. Front Mew of ABC with One Switch Removed.

SUMMARY OF IMPACT

The determination of a handicapped individual's intelligence is trying and often misleading due to the difficulty the person has in communicating their thoughts and desires. The child may either be normally intelligent, but with severe physical limitations that impair communication, or of impaired intelligence that retards comprehension. Communication of some type is important, if only to make the person more comfortable. The lower functioning students have difficulty recognizing that they can have an impact on their environment by the actions they make. The Audio Box Communicator device was successfully versatile and able to help each type of student with their own unique circumstances.

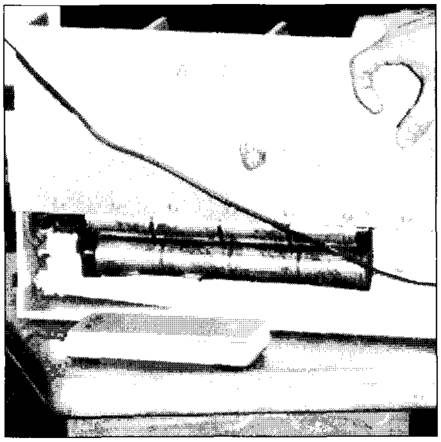

Figure 18.8. Rear View of ABC Depicting Batteries.

TECHNICAL DESCRIPTION

The Audio Box Communicator (ABC) provides a means of communication for teaching and testing the students' knowledge. Items or pictures can be placed above an easily-depressed switch and questions can be asked regarding them. Correct selections are rewarded with light and sound. The student will have the choice of activating one of four sounds or recorded messages by the depression of a switch. One or more of the switches can be deactivated so that the students who have more limited abilities can use the device, without becoming overwhelmed with more options than he or she is able to handle. This feature also prevents reinforcement of incorrect answers as the lights and sound will not be activated. The ABC is constructed from non-toxic Polyvinylchloride (PVC) with the approximate dimensions: $16\frac{1}{2}$" long by 10" tall by 12" wide. It consists of a box with four upper and lower partitions; the partitions are spaced approximately 3" apart. In each of the lower partitions, a 3" wide Bass Switch by Don Johnson Developmental Equipment and red marker light are mounted. The switches are mounted with Velcro strips, enabling simple removal for use by the more physically impaired children. Above the switch is a shelf that an object can be placed on and questions can be asked concerning it. The Bass switch is a light pressure device that can be easily activated by the students with weak muscle structure.

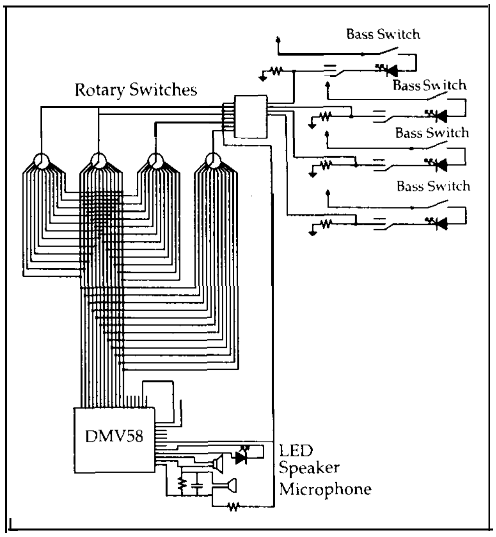

Figure 18.9. Circuit Schematic.

The spoken auditory feedback was provided by the DMV-58 Voice Module by Ming Engineering and a $3\frac{1}{2}$" diameter mounted speaker. It can record up to sixteen different messages or four minutes of speech and allows multiple playback of recorded messages. It requires 9-12VDC to operate and a constant current source of 20 mAmps to prevent memory loss. A tone generator was also incorporated in the circuitry to provide a non-spoken sound pitch. Eight D-size Nickel Cadmium batteries were chosen to power the ABC. An internal MAX713 Nicad-Battery Fast Charge Controller was included so that the batteries could be charged without removing them from the device. Recharging only requires that the device is plugged into a standard 120V wall outlet for 15 hours. The high-capacity Nicads provide 4 AmpHours of power. In the event that the device is not in use, it must be recharged every eleven days to maintain the memory. When a spoken message is played, the ABC device draws 200 mAmps and is able to speak continuously for 20 hours without recharging. In the rear of the ABC device, a rotary switch is located behind each partition to allow volume adjustment of the tone or spoken message. A jack for an AC adapter and the switches for turning the ABC device on/off and recording/playing messages are additionally mounted in the rear of the ABC. The batteries are safely encased behind a lockable piano hinge that is attached to the rear structure of the box. The total cost for the construction of the Audio Box Communicator was $674.

Design of an Adjustable Computer Table

Designers: Norma Brown, James Richardson
Client Coordinators: Gretchen Foster
Gorman Public School
Supervising Professor: Dr. David B. Reynolds
Department of Biomedical and Human Factors Engineering
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INTRODUCTION

The adjustable computer table was designed for a classroom of physically disabled students at Gorman Public School. The students have limited body movement caused by the diseases of spina bifida or cerebral palsy, which impair motor skills and confine the children to a wheelchair. Individually, the students are distinct in height. The elevation of the previously used computer table was only adjustable manually, requiring the strenuous and time-consuming effort of at least two individuals. It was requested that a computer table, adjustable to various vertical heights by the use of an electronically operated switch, be designed in order to conserve classroom time. The range of heights necessary to accommodate the children as they utilize the computer table is from 18 to 29 inches. The pneumatic switch-operated Telemag by the Magnetic Corporation was chosen to implement the adjustable height feature due to its safe, quiet, durable, and low maintenance operation.

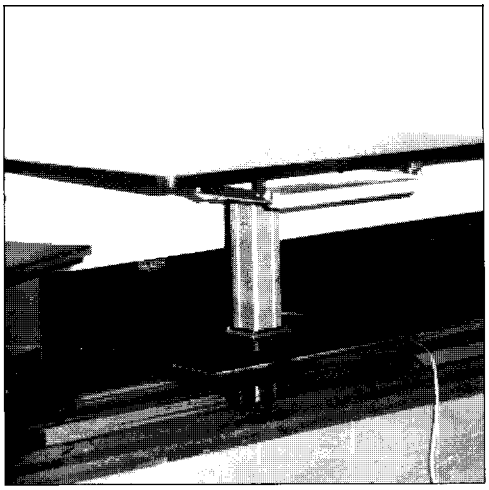

Figure 18.10. Computer Table in Retracted Position.

SUMMARY OF IMPACT

The classroom children were successfully able to adopt the new computer table, without conflict between their wheelchairs and the table's pedestal base. The maintenance-free Telemag provided easy, switch-operated height adjustment of the computer table for the various students' sizes and is much more convenient for the non-technical oriented person than the preceding, manually adjustable table.

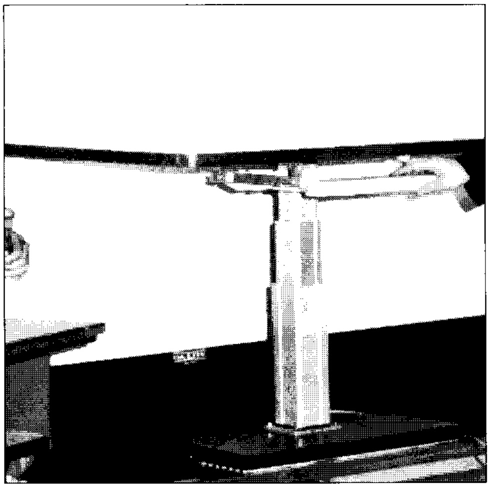

Figure 18.11. Computer Table in Extended Position.

TECHNICAL DESCRIPTION

The design of the height-adaptable computer table involved the assembly of an adjustable height feature, a table top, and a pedestal base. Several specifications were required of the newly designed table by the Gorman School teacher:

- the height must be adjustable within the range of 18 to 29 inches
- the dimensions of the table top, which the computer equipment rests on, must be a minimum of 36 inches long, 28" wide, and be able to support a minimum of 100 lb.

- the computer table must be safely and easily accessible
- the device should not interfere with the students' wheelchairs
- the table must be equipped with a computer keyboard tray that should extend a minimum of 6 inches from the computer table and be adjustable vertically and horizontally.

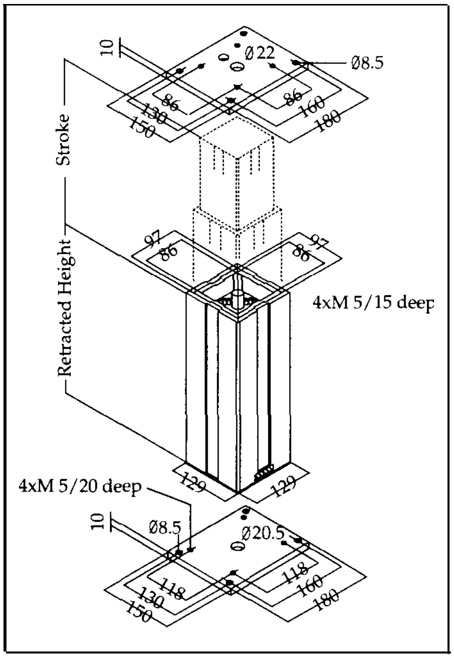

Figure 18.12. Telemag Linear Actuator.

The Telemag is a pneumatic switch-operated linear actuator purchased to provide the adjustable height feature. With the mounting plates attached, it has a retracted height of $14\frac{3}{8}$", an extended height of $26\frac{1}{8}$", and total stroke of $11\frac{3}{4}$". The Telemag consists of three tubular anodized aluminum sections which slide inside each other via a telescoping action. The drive of the Telemag consists of an electric motor with a hollow rotor shaft. The shaft's rotation is converted into linear motion by a spindle/nut system. The Telemag is operated by 120V, standard wall voltage, and a pneumatic switch was mounted to the rear of the table top with Velcro to prohibit student interaction. When loaded with the computer accessories, the Telemag achieves full extension in 20 seconds. This translational velocity of approximately 15 mm/sec has been assessed to be safe. The table top is 48 inches long, 30" wide, $1\frac{1}{8}$" thick, and consists of a wood-packed core covered with a dark, simulated wood Formica. The dimensions of the table were carefully chosen to assure proper clearance for the computer accessories. The table top was attached to the Telemag by a mounting plate and due to the large size of the table top in comparison with the mounting plate, a 12 square-inch aluminum plate was attached to the top of the mounting plate to add stability to the system. The computer keyboard tray was purchased and fastened to the center of the table top's front side.

The semi-circular pedestal base, which the Telemag rests on, has a 13" radius and $1\frac{3}{8}$" thickness, with a 26" long by 5" wide rectangular section attached to its diameter (See Figure 18.13). It is composed of a wood core which is laminated with a wooden-finish Formica. The circular side of the base comprises the rear of the computer table. The chosen shape of the pedestal base allows maximum leg room on the flat side and proper stability of the table on the circular side of the base. A mounting plate was used to fasten the Telemag to the base and to prevent undesired movement of the system on the wooden floor of Gorman School, a rubber mat was attached to the bottom of the pedestal base. The suction cups at the bottom of the mat adhere to the floor and provide a more rigid system.

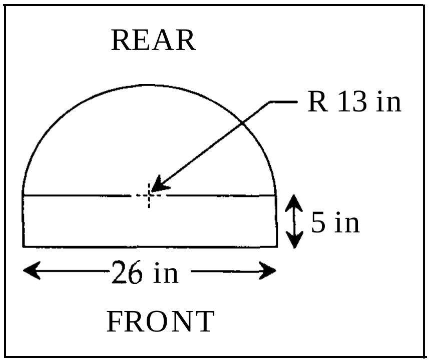

Figure 18.13. Pedestal Base.

An engineering analysis was completed on the computer table to determine the proper dimensions of the base plate and ensure stability of the system, especially when undesirable loading was exerted on the table top. It was found that the computer table was safely operated when forces less than 106 lb. were applied to a corner of the table. The height range of the assembled adjustable computer table was from $17\frac{1}{2}$" to 29" and the final cost of its production was $1086.

Remote-Controlled Switch-Activated Visual Learning Aid

Designers: Zeyad Afifi, Carmen Baker, Miriam McKay
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Supervising Professor: Dr. Thomas Hangartner
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INTRODUCTION

The visual learning aid was designed for a classroom of multi-handicapped students at Gorman Public School. The children collectively suffer from cerebral palsy, Down's syndrome, and a neuromuscular disease similar to multiple sclerosis. Consequently, they have a mental developmental level of only 9-24 months. The device was intended to teach the children through cause and effect play and to aid in visual tracking. A switch-activated mobile on a height-adjustable stand was proposed by the Gorman School teacher. The height adjustment was necessary to accommodate the students as they lay on the floor, sit in a wheelchair, or stand upright. The mobile consists of three interchangeable top designs: a ring with light-emitting diodes (LEDs), multi-colored sprockets, and hooks for hanging objects; a world globe with LEDs at various geographic locations; and a helix composed of multi-colored slats. The top designs are inserted into a base containing the drive system, power supply, and all electronic circuitry. The mobile is designed to be activated by the student's use of a remote control switch. When activated, the mobile will rotate, lights will come on, and music will play. A 6811 microprocessor was programmed to drive the motor, LEDs, and music. Currently marketed mobiles do provide visual tracking for the less developed students, but fail to furnish the specified lights, switch-activation, and an appropriate classroom appearance for children of ages between 7 and 9 years.

SUMMARY OF IMPACT

The interaction of a disabled student with his or her world is a difficult task. They often do not recognize that their actions impact the environment or acknowledge any response. The designed mobile was successful in stimulating the children's senses of vision and hearing, and made it possible for them to interact with and develop an element of control over their environment.

Figure 18.14. Three Mobile Top Designs and Base Housing.

TECHNICAL DESCRIPTION

The visual learning aid consists of five fundamental components: the ring, globe, and helix mobiles, a switch-activated transmitter, and a base that houses all electro-mechanical connections. The ring mobile is 20" in diameter and is composed of lightweight Celtac foam Polyvinylchloride (PVC). It consists of two concentric rings, the outer of which is the location of numerous large, plastic LEDs. The two rings are connected together by eight angled and colored sprockets, and a height-adjustable PVC pole was attached to the center of the inner hub. Through the length of the pole, wires were run from a power source in the base to the LEDs of the outer ring. The spherical mobile consists of a 16 inch diameter world globe, to which twelve LEDs were mounted in geographically significant locations. A height-adjustable pole was likewise attached to the lower surface of the globe. The helix mobile design was constructed from sixty $16 \times 2\frac{1}{2} \times \frac{1}{4}$ cubic inch Celtac slats, centered around a PVC pole, and arranged with spacers by five alternating colors. The significant 30” height of the helix was viewable from the children's various positions without adjustment.

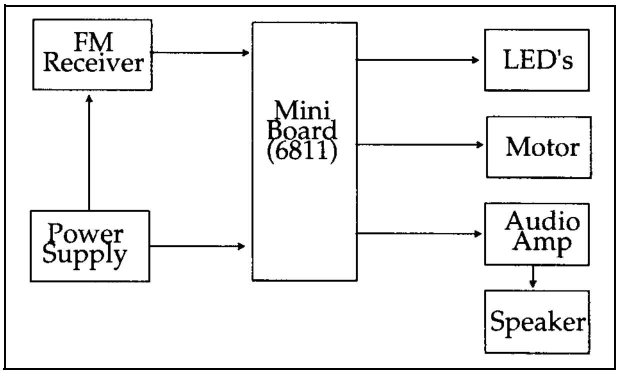

Figure 18.15. Block Diagram of Circuitry

Each mobile and its accompanying pole is snugly fit into a short PVC pole, or shaft, contained within the base. The shaft is connected to a drive system that allows the mobile to rotate. The drive system is powered by a geared 12VDC motor, which is attached to a double flanged pulley. The pulley is then attached by a timing belt to a second, larger double flanged pulley that is fastened to the shaft. In two locations, ball bearings were press-fit around the shaft and set in place with keeper rings. Each bearing was then press-fit into an aluminum plate. The two plates and an additional base plate were connected by aluminum columns to form the support structure of the base. The height adjustment of the ring and spherical mobiles was accomplished through two telescoping pieces of PVC tubing and a plumbing connector which can be loosened and tightened to adjust and lock the desired height of the inner pole, respectively. Rotational motion that could damage the internal wires was prevented by a key and groove assembly within the telescoping poles. Two brass rings were attached to the bottom of each pole. The respective electrical hot and ground wires were run from the LEDs in the mobile to these rings. Once a pole is slipped into the shaft, these brass bands make an electrical connection with the circuit by each touching a pair of spring-loaded metal balls that are mounted within the shaft. The balls are wired to the rotating section of a conductive slip-ring which is fixed to the drive shaft, while the stationary section of the slip-ring is wired to an output port of the Mini Board 2.0. The slip ring prevents wire entanglement as the pole/drive shaft assembly rotates. The Mini Board 2.0, which contains a 6811 microprocessor, is the brain of the circuitry. The mini board is connected to the motor, the LEDs, an audio amplifier and speaker, the remote receiver, a 12VDC lead-acid battery, and a battery charging circuit. The microprocessor was programmed to randomly select and play one of six children's songs.

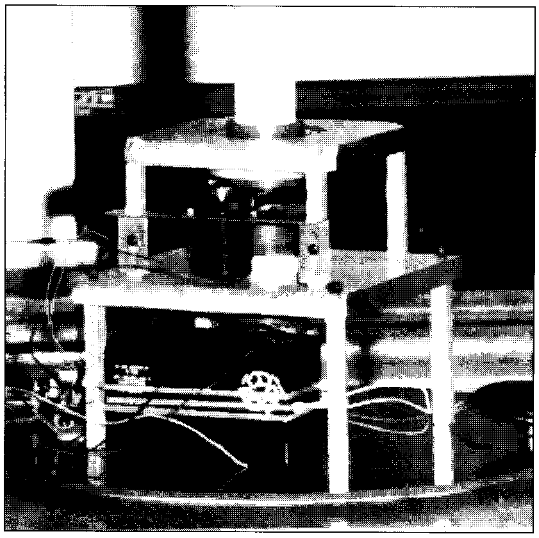

Figure 18.16. Enlarged View of Base.

The activation of the mobile is accomplished through a light-pressure switch that is equipped with a radio transmitter, adapted from a remote-controlled car. The remote receiver, located within the base, activates the rotation and illumination of the mobiles through the implementation of the Mini Board 2.0. The final cost for the production of the visual learning aid was $2,264.

A Low Table Design

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Supervising Professor: Dr. Ping He
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INTRODUCTION

An adjustable low table was developed for a four year old Gorman Public School student, Collins, who has weak muscle tone and poor motor skills. His physical disabilities, which have not yet been attributed to cerebral palsy, instigate swaying movements that prevent him from sitting upright in a chair without sliding. The low table can be used by the student in a kneeling (13” height) or standing (21” height) position, thereby eliminating the troublesome chair. The height variation feature of the low table was accomplished electronically through a pneumatic switch-activated Telemag linear actuator by the Magnetic Corporation. An independent tilt feature and book support were installed on the table top to aid the student as he reads, writes, and draws. Table top angles of 0, 15, 30, and 45 degrees were provided upon client request.

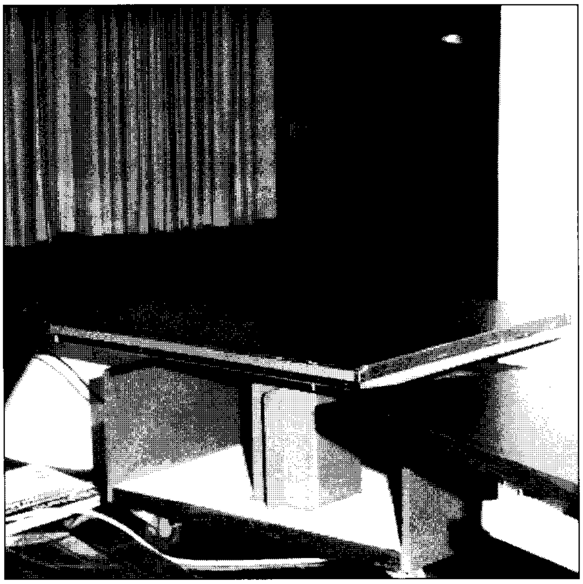

Figure 18.17. Low Table in Retracted Position.

The low tables that currently exist on the market do not offer adjustability of the height and the table top's angle simultaneously. Furthermore, the height of the tables can only be adjusted manually by loosening a set of screws, and with the timely assistance of at least two individuals. In their extended height position, these tables have been found to be unstable.

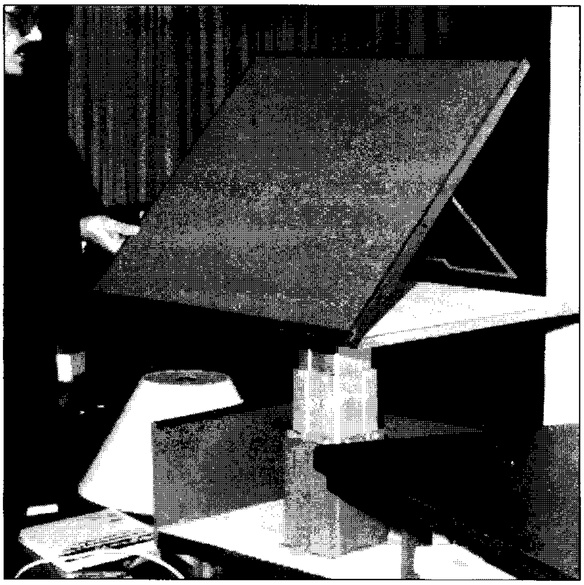

Figure 18.18. Low Table in Extended Position.

SUMMARY OF IMPACT

The designed low table was successfully implemented by the Gorman School student. The teacher operated the adjustment of the table's height and slope easily and the system proved to be safe, durable, and comfortable for the student to employ. The Telemag's simple and quiet operation minimized classroom distraction and the low table made it possible for the disabled student to perform normal activities at a table, despite his physical impairments.

TECHNICAL DESCRIPTION

The low table design incorporated three primary components: the adjustable height feature, the tilt-table table top, and the base. The desired height range of the assembled table was approximately 13” to 21", with the modification provided by the pneumatic switch-operated Telemag.

The pneumatic Telemag is a dual-button operated linear actuator that moves up or down at a rate of 15 mm/sec. Depressing the first button sends a pulse of air to trigger the rotation of a motor in one direction, resulting in height extension. Depression of the second button causes rotation of the motor in the opposite direction and consequently, the retraction of height. To ensure only teacher operation, the switch was mounted to the rear of the table with detachable straps. The Telemag stands 11.55” tall with an available stroke of 9.5”. In order to achieve the designated table elevations of 13” to 21", top, bottom, and side supports for the Telemag were necessarily designed to consume a minimum amount of height.

The table top consists of two stacked pieces of $\frac{1}{4}$" thick plywood. The bottom board, 24” long by 24” wide, was attached to the top of the Telemag and three grooves were made in it at lengths of 22, 18.88, and 13.18 inches from the front of the table. The top board, $24\times23\frac{1}{4}$ inches, was laminated and attached to the bottom board with a hinge at the front of the table. A 2/5" diameter supporting steel rod was then fixed to the lower surface of the top board. The supporting rod can be placed into one of the three grooves of the bottom board, providing tilt angles of 15, 30, and 45 degrees from the front of the low table, respectively (See Figure 18.19). A second hinge, located $\frac{3}{4}$" from the front of the top board, creates a ledge for books when the table top is tilted. A steel book support was additionally fastened to the front of the top board to prevent books from sliding off of the ledge. When the table top is in the slanted position, it can withstand applied forces of up to 50 lb.

A $24\times18\times1$ cubic inch steel framework was constructed to brace the Telemag. Two channel beams, constructed from $18\times2\times1$ cubic inch angled iron were welded to the center of the frame and a top, bottom, and two side u-shaped supports were constructed from $\frac{1}{8}$" thick steel to stabilize the Telemag. The top and bottom supports were fixed directly to the Telemag with screws, forming bridges between the Telemag, and the table top and base framework, respectively (See Figure 18.20). The side supports were fit around the Telemag and screwed into place. The bottom support was then welded to the channels of the base framework, while the top support was fastened to the lower board of the table top. Two inch diameter braking wheels were attached to the framework to provide easy mobility of the low table and a laminated plywood housing was made to encase the Telemag. The final height range of the adjustable low table was 13.85 to 21.85 inches and the total cost for completion of the project was $1,508.

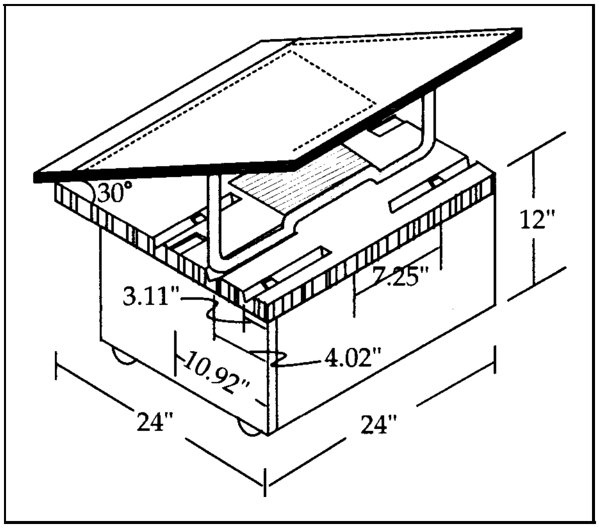

Figure 18.19. Angle Adjustments Using Supporting Rods.

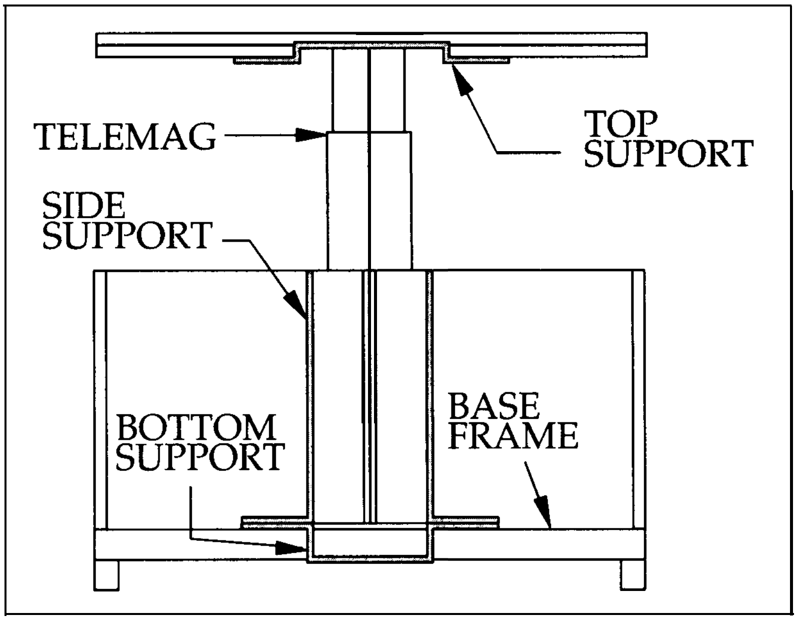

Figure 18.20. Cross-Sectional View of Low Table.