CHAPTER 21
WRIGHT STATE UNIVERSITY

College of Engineering and Computer Science
Department of Biomedical, Industrial and Human Factors Engineering
207 Russ Center
3640 Colonel Glenn Highway
Dayton, Ohio 45435-0001

Principal Investigators:

Chandler A. Phillips (937) 775-5044

chandler.phillips@wright.edu

David B. Reynolds (937) 775-5044

david.reynolds@wright.edu

MULTISENSORY ROOM

Designers: Visar Berki and Renee Woodyard
Client Coordinator: Ms. Joanne Crowson, United Rehabilitation Services
Supervising Professor: Dr. Julie Skipper
Biomedical, Industrial, and Human Factors Engineering Department
Wright State University
Dayton, OH 45435-0001

INTRODUCTION

A multisensory playroom was created for children with an autism, sensory dysfunction and cerebral palsy. The room allows children to explore various sensory stimuli (see Fig. 21.1), stimulating gross motor skills, eye-hand coordination, spatial awareness, and tactile sensation. The design includes a dark wall, a ball chute and an exploratory wall. Switches were placed on the floor of the sensory room for easy access and on the walls to provide a physical challenge.

SUMMARY OF IMPACT

The clients are able to effectively use all elements in the room to experience sensory stimulation.

TECHNICAL DESCRIPTION

The sensory room has three walls and an open ceiling. The room contains durable mechanical and electrical switches. The electrical switches are powered by an AC source. The height of the room is 60”. The floor is covered with carpeting that can be easily cleaned. The room is to be used by two children and one therapist at a time. The open ceiling allows an adult over five feet tall to stand comfortably inside the room. No choking hazards are present.

The dark wall (see Fig. 21.2) has a bubble screen, a color wheel and a light column. The bubble screen has: 1) a timing circuit with 45 LEDs for lighting; 2) a five-and-a-half gallon aquarium to hold water; 3) air mist diffusers to provide bubbles across the aquarium; 4) a nine-volt 30-gallon aquarium air pump; and 5) a foot switch. The foot switch controls the pump. The maximum current of the switch is two amps, while the current rating of the pump is .2 amps. A master power switch, located on the top panel of the sensory room, activates the lighting mechanism. The circuitry controlling the lights includes a 555 timer and a decade counter. Each output controls a total of 15 LEDs each. The LEDs light the water from the top of the bubble screen and change the color from red to green to blue. The color changes every ten seconds. The plywood surrounding the bubble screen is covered in a light green textured fabric. The fabric enhances tactile stimulation and is easy to clean.

Fig. 21.1. Multisensory Room.

Fig. 21.2. Dark Wall and Exploratory Wall.

The color wheel is in the center of the dark wall. A child spins the knob, which causes the wooden frame to spin. Three colors are revealed. The "wheel" is a wooden square frame that is 13″ x 13″. Four triangles were cut out from the wooden square. A 1″ hole was drilled in the center of the frame to insert a dowel rod. Four colors of cellophane (red, green, blue and purple) were placed between two acetate layers. The acetate prevents the cellophane from tearing. The three layers were glued together with Liquid Nails™. The three glued layers were glued to the wooden frame with Sumo Glue™. The plywood (20″ x 60″ x .5″) was covered with blue fabric.

Three triangles, cut out of the plywood, expose the different colors of the color wheel. A dowel rod connects the wheel to a door knob, which allows the wheel to spin. Behind the wheel, two strips of plywood (2″ wide) were joined together in a triangle for support. Two 1″ holes were drilled through the two strips so the dowel rod could pass through the support mechanism, which also spins the wheel. A fluorescent light is mounted on two 17.5″ horizontal studs that are supported by two vertical 57″ studs.

The Light Column consists of a mechanical switch and a logic circuit. The master power switch, located on the top panel, activates the lights. The lights flash on and off with the appropriate count of the decade counter. When the switch is pressed, the lights stay lit as they ascend. Once the switch is released, the lights flash on during the appropriate count and are deactivated on the next clock pulse. The paneling that covers the light column has six holes. The holes are 4″ in diameter and are cut out from the plywood.

Six 5.5″ colored diffusers were mounted behind the holes. The diffusers have colored cellophane glued to the front to protect the cellophane. A layer of acetate was glued on top of the cellophane to protect it. Behind the diffusers are six square pieces of wood that measure 7″ x 7″. The squares have three holes drilled out for insertion of LEDs. The plywood is covered in the same light green fabric as the bubble screen. The mechanical switch has a force resistance that can be increased or decreased by adding or removing any of four springs that are inside. A child must hold down the switch in order to allow each light to stay lit.

The ball chute is the center wall of the sensory room. It includes: 1) a logic circuit; 2) super bright LEDs; 3) diffusers; and 4) clear tubing (see Fig. 21.3). The lights are placed at each turning corner of the tubing. Mechanical momentary switches are inside each of the corners. A child drops a ball in the tubing, which is on a 40″ x 40″ piece of pegboard. Once the ball hits the first switch at the corner, the light adjacent to the corner remains lit. The ball then drops down to the next corner to hit the next switch. This activates a light and deactivates the previous light. There are a total of four corners and four lights. The circuit consists of two dual JK Flip-Flop logic chips connected to a five-volt DC power supply. Each normally open momentary switch was connected from ground to the preset pin of a flip-flop. Once the ball hits the first switch, a low pulse is sent from ground to the preset pin and activates the output Q, which is fed to LEDs. When the ball activates the next switch, it turns on the next light. The Q output of the second flip-flop goes high, making its output low. The low pulse is sent back to the clear pin of the first flip-flop, and it turns the previous light off. The sequence continues until all four lights are activated and then are cleared by a fifth and final switch.

The exploratory wall (see Fig. 21.2) is the final wall of the sensory room. It includes several acoustic instruments (tambourine, shakers, clappers and guiro) mounted on the wall to promote auditory stimulation. All instruments (except the tambourine) were placed in front of colored foam to provide color contrast.

The Brain Game (see Fig. 21.4) was constructed from an electronics kit purchased at Midwest Electronics. It plays a pattern of lights and sounds that must be repeated by pressing one of the four buttons in order to get a positive response. The positive response is a short tune and lights flashing in a circular pattern. If the child presses the wrong button, all of the lights flash on and off. The game was mounted inside a clear display case and installed on the inside of the exploratory wall below the tambourine.

An 18″ x 18″ chalkboard is also affixed to the exploratory wall. The chalkboard is hidden behind a hinged door. The door was made of plywood and mounted by two 2″ hinges. Two grooves were made in both horizontal 2″ by 4″ boards. The horizontal studs were mounted on the vertical studs of the wall frame. The back grooves hold the mirror into place, while the front grooves allows the yellow door to slide open, revealing a mirror.

The exploratory wall includes a set of mystery pockets with buttons and a mystery box with laces. The mystery aspect was incorporated to encourage children to unfasten the buttons or the lace. The child receives positive feedback by receiving his or her favorite toy once he or she opens the pockets. In this device, the state of each of the lights, located on all four edges, depends on whether force is applied to each corresponding switch. A knob on a track guides the child to each switch that activates a light

The cost of the parts and labor was about $1050.

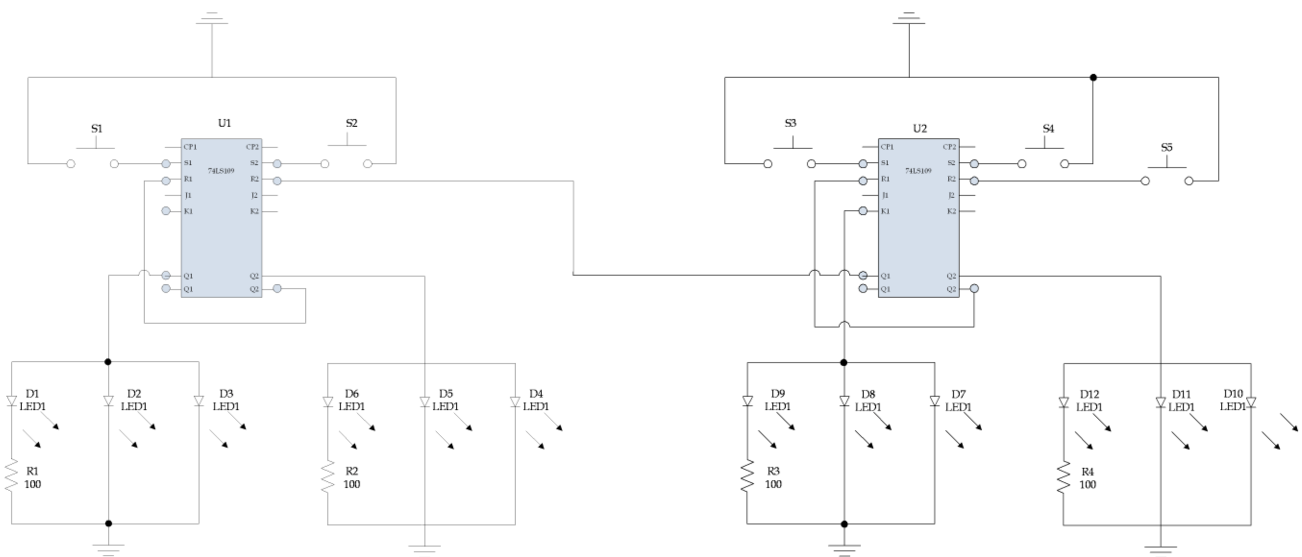

Fig. 21.3. Diagram of Ball Chute Logic Circuit.

Fig. 21.4. Client Interacting with Brain Game.

CUSTOMIZED HEIGHT-ADJUSTABLE TABLE TOP

Designers: Stephanie Auld and Ryan Foster
Client Coordinator: Ms. Cassandra Hoagland, Gorman Elementary School
Supervising Professor: Dr. David Reynolds
Biomedical, Industrial, and Human Factors Engineering Department
Wright State University
Dayton, OH 45435-0001

INTRODUCTION

The Customized Height-Adjustable Table Top is a table with a section that can be raised and tilted to accommodate a person using a tall, tilting wheelchair (see Fig. 21.5). The device was created for a student with physical disabilities who uses a wheelchair that tilts backwards at an angle of approximately 15 degrees. The device allows the client to complete in-class activities. The table accommodates groups of students in wheelchairs, including taller wheelchairs, such as the one used by the client. The table has three sections : two are fixed and the third (middle) section may be raised and tilted.

SUMMARY OF IMPACT

The device improves the ease of teacher-student interactions in the classroom. The client is able to access the raised and tilted portion of the table top, while the teacher assists the client from the opposite side of the table. The client coordinator stated, "This is perfect, exactly what I asked for." The device allows the client to be more involved in group interactions as well.

TECHNICAL DESCRIPTION

The table design utilizes basic geometric angles. The acute angles between the three sections of the table are 45^{o}. The surface of the table top is white shelf plywood. A frame of 1″ x 6″ hardwood board supports the bottom of each non-adjustable section of the table top. The support frame decreases the possibility of the table bending and sagging. A white border material was placed around the edges of the shelf plywood to smooth out the edges and provide a more uniform appearance. The eight legs are made of 1.25″ inner-diameter metal piping. Eight 1.25″ flanges are attached to the support frame on the bottom of the table. The ends of the piping are threaded, which allows them to screw into the flanges. Rubber stoppers were placed over the other end of the legs to minimize slippage.

Fig. 21.5. Client Using Adjustable Table Top.

The height adjustment mechanism has: 1) two bracket arms; 2) four side plates; 3) eight rotating pins; 4) a double-ended spring loaded pin; 5) two gas-assisted extension struts; and 6) a lever arm (Fig. 21.6). Aluminum 7170 was used to construct all of the structural components of the mechanism. A force analysis of the adjustable section of the table top was conducted to determine the required properties of the gas struts and then two sets of the struts were selected.

The height-adjustable portion can be raised to a level of 31.125″. The maximum degree of tilt is 15.5^{o}. The maximum tested load of the height adjustment mechanism was 140 lbs. The steps to adjust the table top are: 1) grip the table top; 2) press the lever arm to unlock the pins; 3) move the table top to the desired height or tilt it; and 4) release the lever arm.

The total cost of the parts and labor was $910.

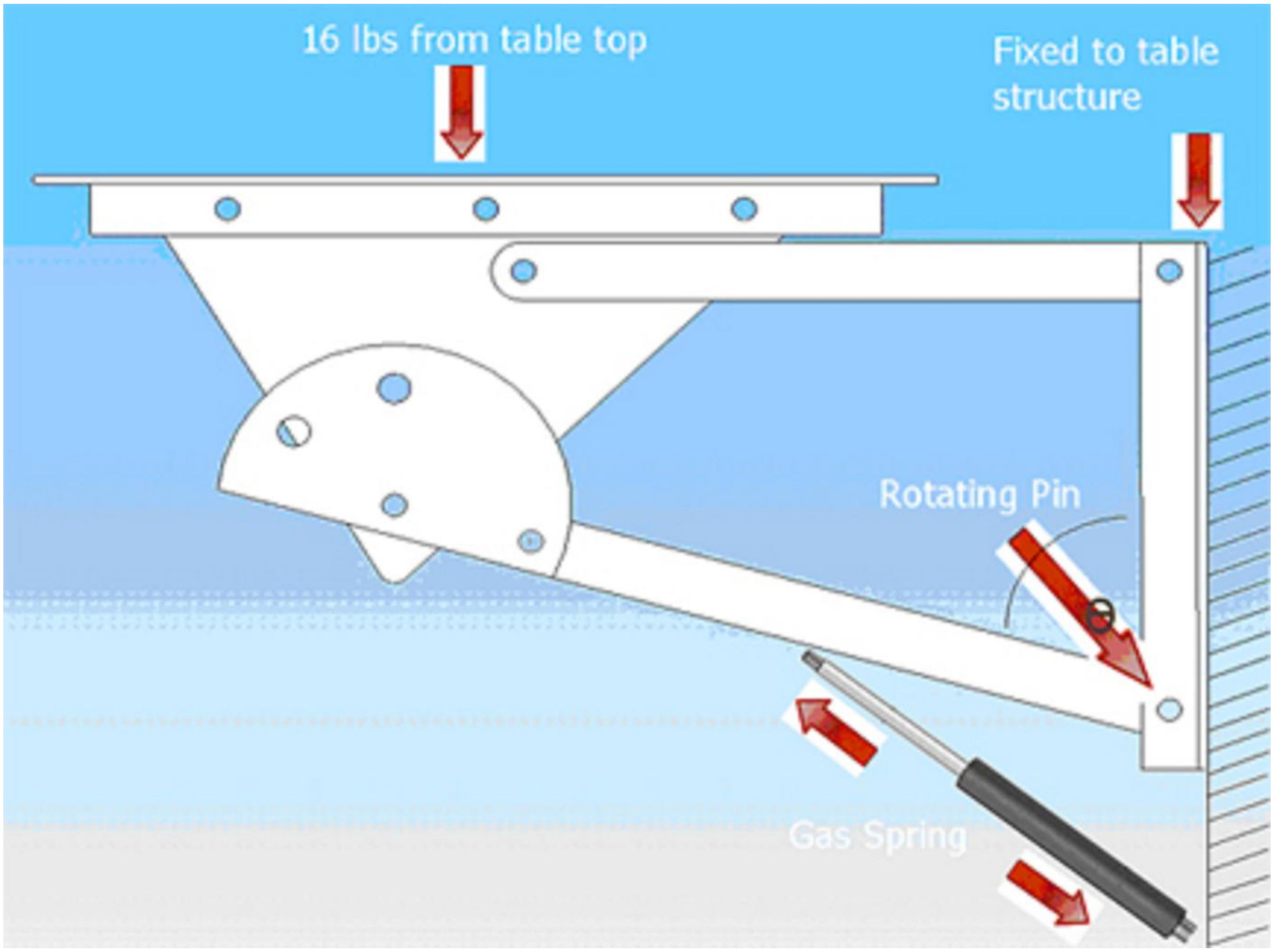

Fig. 21.6. Height Adjustment Mechanism.

CANDY SORTER

Designers: Brian Bottenfield and Nathan Busick
Client Coordinator: Mr. Guy Parworth, United Rehabilitation Services
Supervising Professor: Dr. Chandler Phillips
Biomedical, Industrial, and Human Factors Engineering Department
Wright State University
Dayton, OH 45435-0001

INTRODUCTION

A candy sorter was created to help distribute random candies into a container (see Fig. 21.7). The objective was to modify a past candy sorter design into a more functional one. The device was developed to help individuals with physical disabilities sort and count candies so that they can make candy wreaths.

The final product is based on the previous design, involving a rotating drum that pushed the candy down a series of ramps and into the appropriate containers. The drum was unchanged, but the ramp system and controls were simplified. The candy is put into the drum, and the drum then spins, according to user input, and pushes the candy to the ramp. The candy then slides down the ramp into a container. The container is on a spinning platform with three other containers. When the container is filled, the user triggers the spinning platform to turn so that a new container can be filled.

SUMMARY OF IMPACT

The candy can be counted by the client and sorted into separate containers based on the client's control of the device. The device increases the client's

Fig. 21.7. Client Using Candy Sorter.

independence. The client coordinator and the client were both satisfied with the delivered product.

TECHNICAL DESCRIPTION

The device has two individual and separate apparatuses. The drum/ramp portion (Fig. 21.8) is made of a combination of materials. The base structure is made of hard lumber, the rotating drum is made of fiber glass, and the ramp is made of Sintra plastic. All of the fastening was done with a variety of different size steel screws. The drum assembly is 37 " long and 18.5" wide. The total height measured from the ground to the top of the drum when fully tilted is 40". The drum is center-mounted to a high-torque DC motor. A switch (used by the client) completes the circuit between the motor and the power supply. Pressing the switch makes the drum rotate; releasing the switch makes it stop. Inertia and internal braking in the motor prevent the drum from spinning freely.

The second section is the rotating carousel. The base is made from hard lumber, and the top section is made from foam laminate and plastic. Fastening was done with steel screws. The rotating carousel is 23 "wide and 23" long. The height from the ground to the top is 9". For proper rotation, the clearance should exceed 33". The rotating platform is mounted onto a stepper motor. The client has a switch that is pressed to rotate the platform 90 degrees. When the client presses the switch, a signal is sent to a BASIC Stamp II microcontroller. The microcontroller instructs a stepper motor controller (the Little Step-U) to activate the stepper motor.

The length of the power cords is 24" and the maximum distance the controller can be from the unit is 36". The maximum weight limit is approximately that of 15 small wrapped hard candies per receptacle. The drum capacity is approximately 200 similarly-sized candies.

The total cost of the parts and labor was $925.

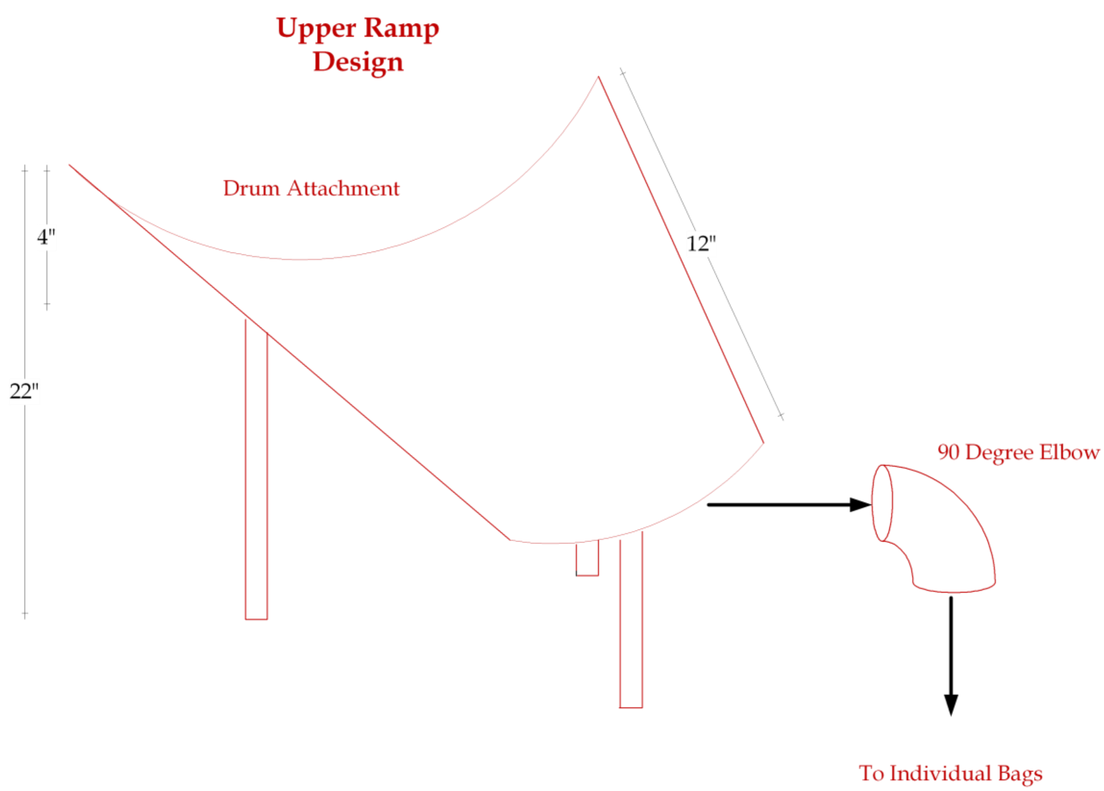

Fig. 21.8. Ramp Design.

NO-TOUCH SOAP DISPENSER

Designers: Roshanak Dezfoolian and Erin Kleismit
Client Coordinator: Ms. Elaine Fouts, Gorman Elementary School
Supervising Professor: Dr. Ping He
Biomedical, Industrial, and Human Factors Engineering Department
Wright State University
Dayton, OH 45435-0001

INTRODUCTION

The No-Touch Soap Dispenser is a device that dispenses a specified amount of soap using a motion sensor (see Fig. 21.9). The client coordinator requested a device for children to replace standard soap dispensers in a restroom at an elementary school.

The device is a motion activated control unit. The device is wall mounted with an extension. It has a pre-determined delay for dispensing the soap to minimize the amount of soap wasted from repeated dispensing. The device is washable, battery-operated, and wall-mounted. It has a low battery indicator that notifies the clients when the battery needs to be changed.

SUMMARY OF IMPACT

The dispenser is fixed to an extension box that makes the device more accessible for small children. Only one hand is needed to operate the product. The motion activation feature decreases the possibility of cross contamination. The time delay minimizes the amount of soap that leaks, which reduces risk of falls and prevents messiness. The client coordinator expressed satisfaction with the final product.

TECHNICAL DESCRIPTION

The device consists of a commercially purchased motion sensor soap dispenser that was modified to increase the time delay after the first delivery of soap to approximately 12 seconds. The time delay device is triggered by the falling edge of a square wave output from an eight-bit micro-controller. The RC time constant produces a delay of 10.8 seconds. With the commercial soap dispenser's own internal delay, the total delay of the final product is roughly 12 seconds. A low-battery indicator was also added; it sounds when the battery level drops to 4.5 volts. The soap dispenser is on a hollow wooden extension box measuring 27.5″ x 12″ x 12″. It extends the product out from the wall by 4″. The soap dispenser is 8.375″ x 4.75″ x 3.5″, which extends the product 15.5″ from the wall. The wooden extension box is covered with Formica so that it is easy to clean and is water resistant. There are pre-drilled holes in the back of the box for simple mounting to the wall. The prototype board that houses the electronic circuits is placed inside the box and the buzzer protrudes from the bottom of the box. The electrical components on the prototype board are: 1) resistors; 2) capacitors; 3) integrated circuits; 4) diodes; 5) a potentiometer; 6) 24-gauge wire; 7) solder; 8) and flux. The user must first insert the batteries and then place one hand approximately 2.75″ under the motion sensor, which triggers the motor to deliver 1 milliliter of soap. There is approximately a 12-second delay before the product can be used again.

The total cost of parts and labor was $525.

Fig. 21.9. Client Using No-Touch Soap Dispenser.

FOOT-ACTIVATED CAUSE-AND-EFFECT TOY

Designer: Jacalyn Jones
Client Coordinator: Dr. Debbie Santiago, United Rehabilitation Services
Supervising Professor: Dr. Thomas Hangartner
Biomedical, Industrial, and Human Factors Engineering Department
Wright State University
Dayton, OH 45435-0001

INTRODUCTION

The Foot-Activated Cause-and-Effect Toy is a toy with interactive components triggered by wireless foot pedals. The device was created for young children who are not familiar with cause-and-effect relationships. The foot-activated pedals activate visual, tactile, and audiotry stimuli.

The client coordinator requested a modification of an existing toy already in use. The existing toy was a small play tent with various stimuli that were activated via switches. The activating switches were required to be enclosed in foot pedals. These foot pedals are wireless in order to accommodate children of different heights and body structures. The client interacts with the device by lying on the floor, within the tent, and pressing the pedals with his or her feet (see Fig. 21.10).

SUMMARY OF IMPACT

The pedals are durable, compact, washable, and adjustable. They insure user safety and maximum enjoyment while teaching cause-and-effect relationships. Children with limited upper extremity control are able to interact with the device.

TECHNICAL DESCRIPTION

The foot pedals are made out of plastic and metal components (see Fig. 21.11). The case structure is comprised of a plastic commonly used as fascia for installing windows. The metal components are: 1) springs; 2) nuts; 3) bolts; 4) washers; 5) screws; and 6) rivets. The surface areas of the pedals that contact the feet were designed to comfortably fit an average foot size. The contact surface is covered with

Fig. 21.10. Client Using Foot-Activated Cause- and-Effect Toy.

sandpaper to provide grip. The part of the pedal that contacts the floor encloses the electronic components. All of the exposed outer surfaces are washable.

The foot pedals enclose the activating micro switches and the wireless transmitter. Each pedal contains two micro switches. Stops were affixed to the pedals to prevent them from being pushed past the point of activating the second micro switch. The transmitter is secured to the connection between the pedals with Velcro, so it can be easily removed to change the battery.

The foot pedals are affixed to a plastic mat with Velcro. The strips of Velcro allow the pedals to be moved to accommodate users of different sizes.

The total cost of parts and labor was $475.

Fig. 21.11. Completed Foot Pedals with Exposed Internal Structure.

TOTAL ANKLE REPLACEMENT

Designers: Shawn Gargac and Ashkahn Golshani
Client Coordinator: Dr. Tarun Goswami, Miami Valley Hospital
Supervising Professor: Dr. Tarun Goswami
Biomedical, Industrial, and Human Factors Engineering Department
Wright State University
Dayton, OH 45435-0001

INTRODUCTION

The goal of this project was to design a replacement ankle joint that will relieve the symptoms of severe ankle arthritis by reducing pain and restoring normal movement, gait, alignment, and stability to the joint. The products were designed to replace current designs that have high complication rates and excessive bone resections.

Three different ankle implant models were developed (see Fig. 21.12). One is a primary design, while the others are revision case designs. The first design is intended for use as the primary implant for initial replacement of an arthritic ankle joint. The second and third designs are for use in revision surgeries in which a previous ankle implant has failed and must be replaced.

SUMMARY OF IMPACT

The designs were tested using Finite Elements Analysis and meet all required specifications. These designs should reduce the complications associated with existing implants. The designs meet all surgical requirements. They may be manufactured in a cost-effective and reliable way.

TECHNICAL DESCRIPTION

The first and primary design consists of three components. The first components is the tibial component, which fits into the inferior end of the tibia. The tibial component contains a trapezoidal superior ridge that is designed to fix the component within the tibia. The tibial component also contains two triangular ridges on the medial and lateral ends. These ridges are designed to provide additional surface area and stimulation for bone growth to help fix the component. The upper portion of this component is coated with a porous coating, which aids in its fixation. The component is made of metal Titanium 6-Aluminum 4-Vanadium (Ti-6AL-4V).

Below the tibial component is the bearing component. This component is manufactured from ultra high molecular weight polyethylene (UHMWPE). The superior surface contains unique rotation protrusions that snap into corresponding holes in the bottom of the tibial component. The protrusions allow approximately 5 degrees of external and internal rotation of the joint. The bottom surface of the bearing component is shaped to match the articulation surface of the third component, the talar component. The curvature of the articulation surface is designed to limit talar shift and provide stability to the ankle joint.

The talar component is also manufactured out of Ti-6Al-4V and will articulate with the bearing component to allow the ankle joint a normal range of motion. The implant provides 25 degrees in both dorsiflexion and plantarflexion. The talar component is designed to fit over the talus like a "cup". The talus is prepared by chamfering all four sides and then slightly flattening the top. The bottom of the talar component also contains a pin, which provides additional fixation to the bone. A porous coating is applied to all surfaces that contact the bone as the method of fixation.

The second design is used for a revision or secondary surgery. It is a four-component design. It consists of a tibial component made of Ti-6Al-4V, and a middle bearing component, which has a C-ring implemented for a pop-fit fixation between the tibial and poly bearing components. Both the bearing component and C-ring are made of UHMWPE. The talar component is similar to that of the other designs and is made of Ti-6Al-4V.

The tibial component has a long spike on the top to give a larger fixation surface area with the bone. It is longer than other primary surgery designs. The spike has a three-stacked conical structure with slightly chamfered sides; the top piece is semi-spherical. The superior surface of the tibial component contains two triangular ridges on both the medial and lateral sides, which perform the same function as in primary design. A porous coating is added to the superior aspect of this component to add additional bone fixation on a cellular level. The medial and later ends have a slight overhang over the bearing component to minimize the amount of debris and growth between the components. The overhangs allow for a slight degree of rotation to reduce stress on the implant. The inferior surface of the implant contains a groove into which the bearing component is inserted.

The superior face of the bearing component contains a protruding structure that fits into the tibial component. The farthest superior and inferior cylinders have the same diameters and are slightly larger than the cylinder between them. The C-ring fits around the center. The C-ring is inserted onto the protrusion by slightly expanding and then snapping into the place in the middle. The C-ring then shrinks as it is fit into the tibial component and then snaps into place to hold the two components together. The inferior surface of the poly bearing component is curved and grooved to fit the articulating surface of the talar component. This groove helps keep the components aligned and allows for 20 degrees of dorsiflexion and plantarflexion.

The talar component has a superior aspect, which has a grooved geometry in the medial/lateral plane and curved geometry in the anterior/posterior plane. It also has stoppers at the ends of the articulating surface to limit the range of motion to 20 degrees dorsiflexion and plantarflexion. The inferior aspect is covered in porous coating to allow bone in-growth and has a chamfered base to allow for press-fit fixation and to provide additional surface area for fixation.

The third design also consists of three components and is intended for use in revision or deformity cases when the first two designs are not able to be used. There is a tibial component made of Ti-6Al-4V. The tibial component consists of two trapezoidal ridges that help fix the component to the tibia. A porous coating is applied to the surfaces in contact with the bone. The bearing component is made of UHMWPE and also allows for internal and external rotation of the joint. The protrusion on the top of the bearing component is a cylinder with a small ring extending from it that snaps into a matching groove in the tibial component. The talar component fits over the talus by the same method as the primary design. It is constructed out of Ti-6Al-4V. The only difference from the primary design's talar component is the articulation surface, which is flat.

The total cost of parts and labor was $1210.

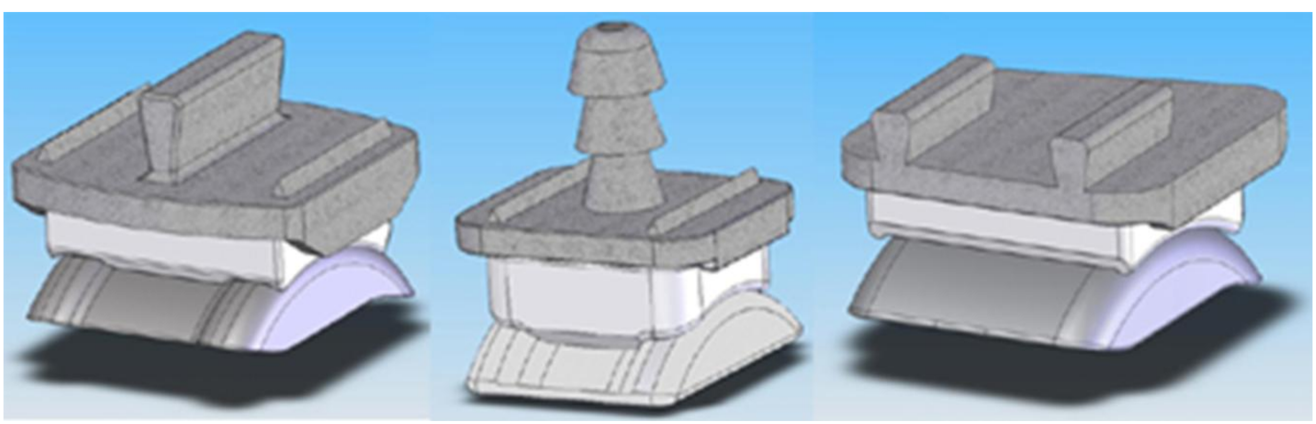

Fig. 21.12. Primary Ankle Replacement Design and Second and Third Revision Designs.