Chapter 5
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WHEELCHAIR CONTROL SIMULATOR

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INTRODUCTION

A wheelchair control simulator was designed so that children could practice using controls typical of motorized wheelchairs while a therapist monitors their progress. The wheelchair control simulator includes a joystick, a processing and display unit, a video monitor, and a custom motorized car with a CCD camera mounted to the front. As a child drives the car through a maze, sensors on the car detect when the car hits a wall. The number of hits, the time moving, and the elapsed time are combined into a running score that motivates the child and provides feedback to the therapist. A four-section LED display indicates the time moving, total time, overall score, and number of hits to each of the four sensors. The monitor shows the camera's view to provide the child with the sense of sitting in the car. This device can be used by therapists to assess whether a child will be able to operate a motorized wheelchair safely. At the same time it is entertaining for the child.

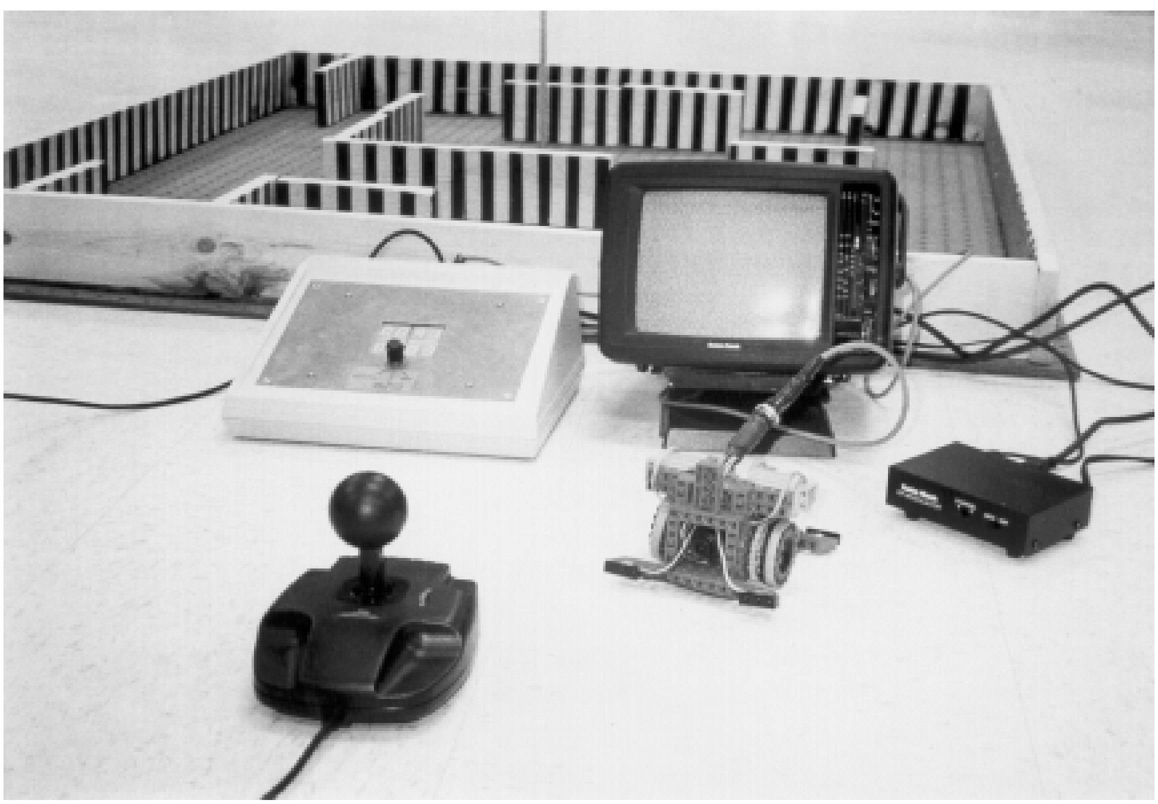

Figure 5.1. Components of Wheelchair Control Simulator.

SUMMARY OF IMPACT

Each year about 50 children at Lenox Baker Children's Hospital could benefit from motorized wheelchairs. Because such wheelchairs are expensive and potentially dangerous, therapists must assess whether a child could benefit from a motorized wheelchair, and if so, whether they are ready to try driving one. The wheelchair control simulator allows children to practice "driving" while the therapist monitors their skills with a running score.

Experience with the simulator to date indicates that two modifications could greatly improve its usefulness. First, using radio control rather than a wire tether would improve the car's maneuverability, since the car has a limited range and sometimes does not turn properly. Second, the switches that sense hits to walls could be more sensitive and reliable. These improvements may be addressed in a future design.

TECHNICAL DESCRIPTION

The wheelchair control simulator has five main components: a joystick, a processing and display unit, a motorized car, a monitor, and a maze, as shown in Figure 5.1. The joystick, a modified Radio Shack Avenger 700, controls the movement of the motorized car. The aviator style handle of the joystick is replaced with a 1.75-inch diameter ball to simulate a standard wheelchair joystick, which was not used because of cost. The joystick is attached to the processing and display unit using a 15-pin D-subminiature connector.

The core of the processing and display unit (Figure 5.2) is the Z180 microprocessor on the SmartCore Z1 Board (Zworld Engineering, Davis, CA). The microprocessor program was developed in Dynamic C using the SmartCore Development Board (Zworld). The microprocessor receives input from touch sensors and a display mode selector switch via a 74LS373 latch. Output from the processing and display unit appears on a four-section LED display, each section comprising two seven-segment digits. This unit serves several functions: to control the movement of the motorized car, to process information from the touch sensors, to control the display, and to provide a power supply. The unit converts the nonlinear output from the joystick into an amplified, linear input for the motors of the car. This is accomplished using a dual analog to digital converter (ADC0844), low pass digital filters, a dual digital to analog converter (DAC0890), and two push-pull current amplifiers. To process information from the touch sensors, a software loop on the SmartCore reads data continuously from the input register (74LS373). The microprocessor counts a hit only if it registers on five consecutive loops, preventing a hit from being counted more than once.

The microprocessor also continuously monitors the signals from a three-position rotary switch and displays either: 'Time Moving and Total Time', 'Hits' (the number of hits on each of the four touch sensors), or 'Overall Score and Total Time'. A real time clock on the Z1 board keeps track of the total elapsed time. The following equation is used to compute the score:

$$\text{Overall Score} = (1000 - 10 * (\text{total hits})) * (\text{time moving}) / (\text{total time}).$$

The motorized car is constructed from Legos with all pieces secured with epoxy to ensure durability. Separate motors drive each of the rear wheels of the car so that a tight turning radius is achieved. The speed and direction of each motor is controlled by altering the amount and polarity of the voltage and current applied to the motor, thereby allowing the car to move in any direction. Each motor is geared down three times to reduce speed and increase torque. Touch sensors are attached to each of the four corners of the car and a CCD camera is bolted in the interior of the car. The car is equipped with bumpers to protect the camera, and a wire tether connects the car to the processing and display unit. The tether contains a total of nine wires: one for each of the ground sensors, two for the CCD camera, one for each of the two motors, and a common ground.

A standard five-inch black and white television monitor displays the output of the CCD camera. The processor and display unit can be attached to any television, using the Channel 3 and 4 modulator included in the unit. The maze is made of a 4'x4' pegboard base with 1"x4" wooden blocks, each with two protruding dowels on the bottom to attach to the base. The wooden blocks may be placed in any desired orientation by the therapist depending on the child's skill level.

The total cost of the wheelchair control simulator was approximately $830.

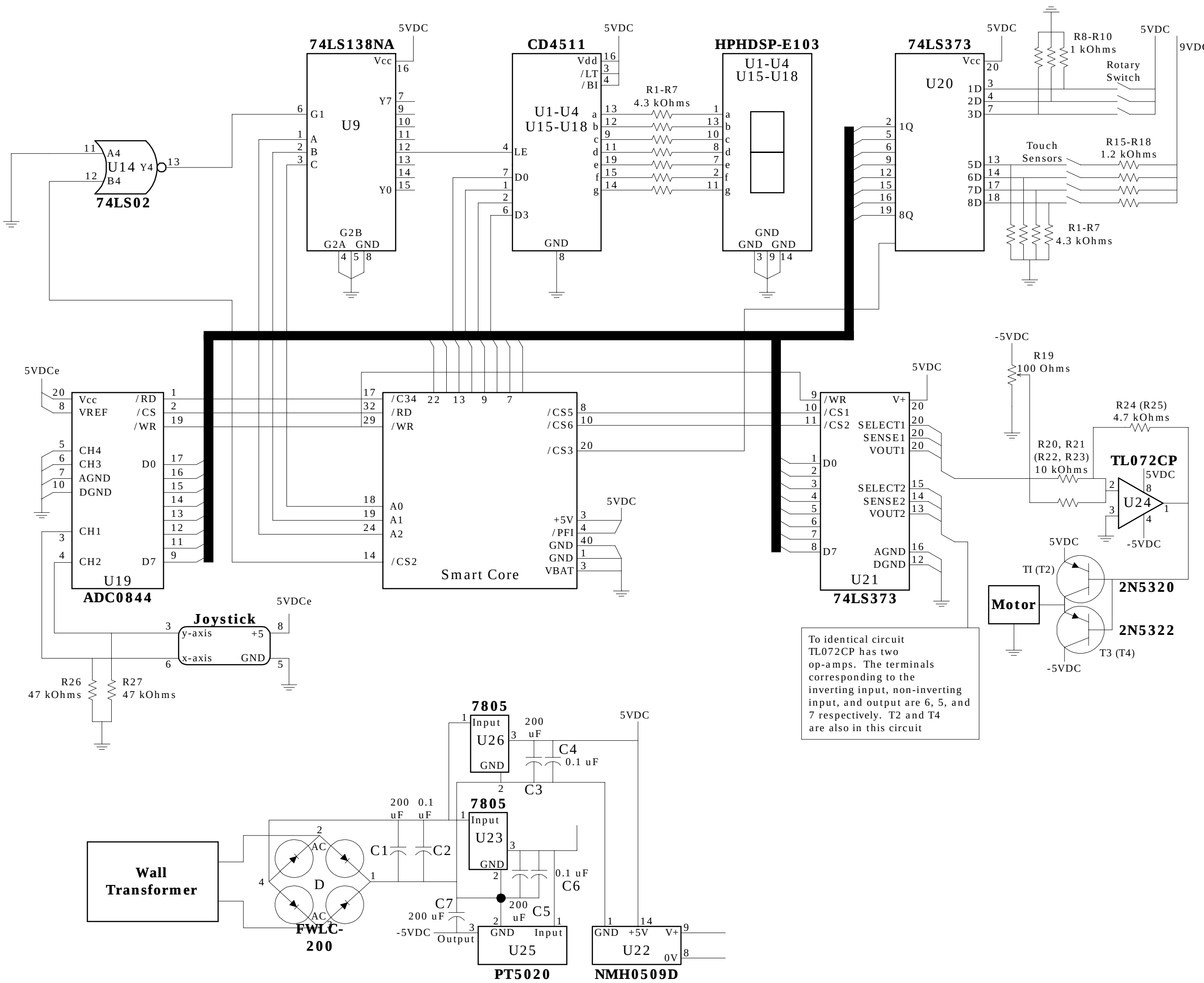

Figure 5.2. Schematic of the Processing and Display Unit.

HOCKEY GOALIE SLIDER

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INTRODUCTION

A hockey goalie slider has been designed for an eleven-year-old boy with cerebral palsy, to enable him to better participate in neighborhood street hockey games. The basis of the slider is the monorail track of a Concept II™ (Morrisville, Vermont) Indoor Rower. The custom seat is situated so that it slides laterally on the track. Using this device, the client can use his legs as well as his arms to move from side to side. Leg extensions and feet prevent the device from tipping or sliding on the pavement. The seat can be adjusted for added comfort, and telescoping legs allow the seat height to be varied to accommodate the client's growth. A Velcro safety belt secures him safely to the slider. Wheels and handles are mounted on the slider for portability. Finally, a custom stick with a rounded handle allows the client added control in stopping the puck.

SUMMARY OF IMPACT

The client has a form of cerebral palsy known as pyramidal diplegia. This type of cerebral palsy renders one's legs weak, and results in a lack of lower body coordination. The hockey goalie slider allows the client to participate more actively in neighborhood street hockey games with other children, including his twin brother who does not have cerebral palsy. Previously, the client had played goalie by sitting in front of the goal with his legs to the side. The slider allows him to sit in an upright position, where he can cover the goal more easily and follow the game better.

The hockey goalie slider also enables therapeutic activity. By using his legs to slide across the goal mouth, the client builds lower body strength and improves coordination. The hockey goalie slider has proven to be safe, durable, portable, and fun. Because the height and seat positioning are adjustable, the client will be able to enjoy it for years to come.

TECHNICAL DESCRIPTION

The hockey goalie slider is comprised of five components: a rail, telescoping legs, feet, a seat, and side pads. The rail is the track monorail from a Concept II™ Indoor Rower, which was generously donated by the company. It is constructed of I-beam aluminum extrusion with a thin stainless steal overlay on the top surface. The sliding mechanism uses eight roller bearings, four contacting the underside of the beam and four contacting the topside of the beam. Rubber stops are attached to each end of the rail to prevent the seat from sliding off the end. The width of the slider is 48 inches to accommodate the size of the standard hockey goal.

Telescoping legs are used to adjust the height of the slider. These legs were obtained from a Parabody weightlifting-spotting stand and are bolted to the monorail. The legs allow the height of the seat to range from 15" to 20".

To insure that the device cannot be tipped either frontward or backward, extensions were added to the legs of the slider. Each consists of a 14" long, 2" wide, ¼" thick steel bar that slides into the legs of the Parabody stand. These extensions are secured by setscrews. Rubber feet are attached to the end of each extension to prevent the apparatus from sliding on the pavement as the client slides back and forth.

The seat cushion was donated by Health Care Equipment (Chapel Hill, NC), and the seat back is custom made to match. Both are upholstered with black vinyl and foam padding. The cushion is bolted onto an aluminum plate mounted on the sliding mechanism. The back support is vertically adjustable using a knob in the J-bar that attaches the back support to the aluminum plate. Horizontal seat adjustment is achieved via a slot in the J-bar where it attaches to the plate, allowing the seat to be adjusted forward or backward relative to the sliding rail. The seat is also angularly adjustable using the bolts that anchor the seat. The seat rests on springs that add cushion and shock absorption. A 3-inch wide Velcro safety belt holds the client securely in the seat and can be attached and removed by the client.

Vertical side pads, made from modified seat cushions, are mounted on fixture brackets and attached to the ends of the rail. These allow the client to move laterally by pushing with his arms and elbows. A knob allows the height of the side pads to be adjusted.

A custom stick was also made by attaching the aluminum handle from a fishing net to the blade of a street hockey stick. The round handle allows the client to maneuver the stick more easily than he could maneuver his previous stick.

Empirical testing shows that the slider is safe, durable, usable, and portable. Theoretical testing of the device suggests that it cannot be tipped over.

The total cost of the hockey goalie slider was approximately $550, including $125 in machining costs.

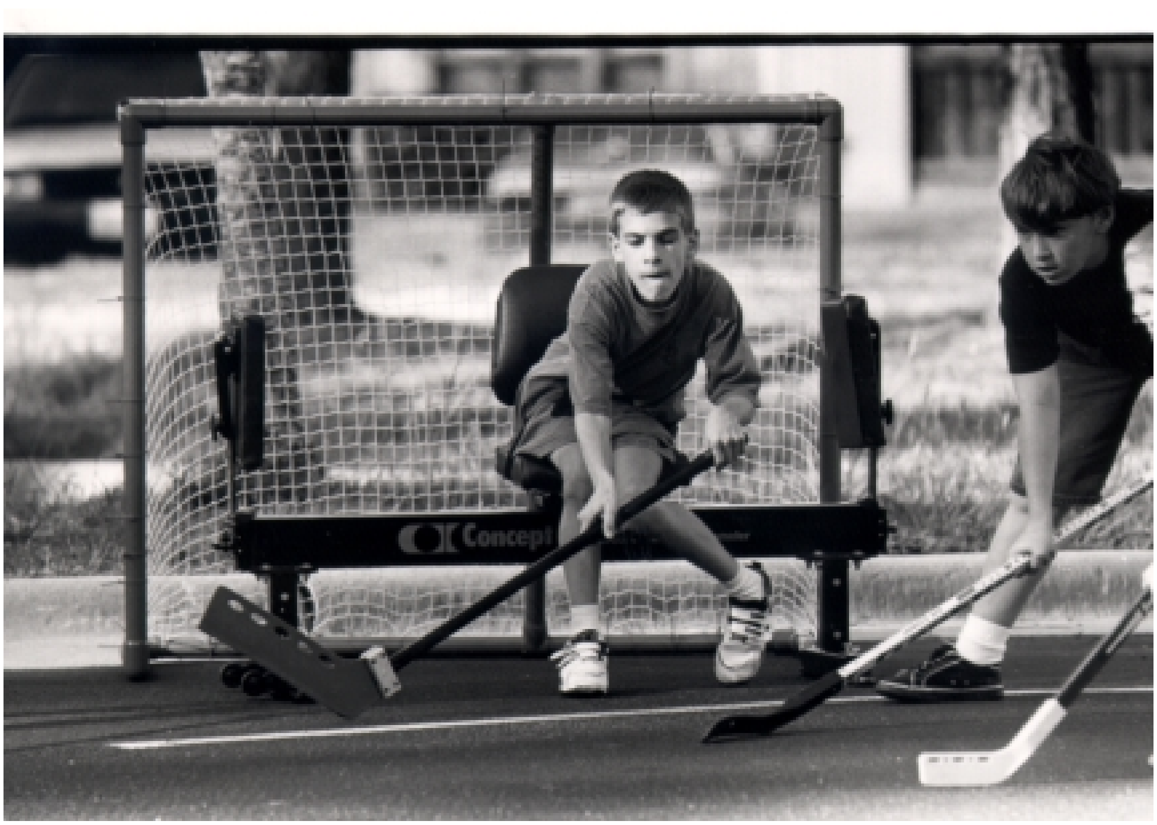

Figure 5.3. Hockey Goalie Slider.

SPELLING AND TACTILE IDENTIFICATION GAME

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INTRODUCTION

A spelling and tactile identification game has been designed as an enjoyable learning tool for children with visual impairments. The device operates in two modes: spelling or tactile. In spelling mode, the device asks the child to spell a word by selecting the appropriate buttons on a custom keyboard. In tactile mode, a grid is placed over the keyboard, which allows the placement of 21 objects. The device asks the child to find a specific object and to push the corresponding button. In either mode, the parent or therapist may choose from six different Braille keyboard overlays so the child cannot memorize the positions of the objects and letters. In both modes, the child is told whether he or she is correct or if he or she should try again. A microprocessor controls digitally recorded voice chips, which ask the child to spell words or find objects, and tell him or her whether or not the correct answer is given.

SUMMARY OF IMPACT

The spelling and tactile identification game is designed to be both educational and entertaining. It is intended for use by children with visual impairments. The design is versatile, operating in either spelling or tactile mode using six different overlays. Unfortunately, the device must be connected to a PC computer, which is unavailable in the playroom of the client's agency. A standalone version of the project, which will not require connection to the PC, is under development.

TECHNICAL DESCRIPTION

The spelling and tactile identification game includes four main components: the input section, the processing unit, the voice chips, and a speaker. The input section consists of two switches and a custom keyboard. A three-position switch determines whether the machine is in spelling mode, in tactile mode, or off. A six-position rotary dial switch selects which overlay is being used. The keyboard consists of 28 push buttons arranged in four rows of seven buttons. In spelling mode, the keys correspond to the 26 letters of the alphabet, plus an "enter" key and a "next word" key. One of six different overlays may be chosen, each containing a Braille letter label for each switch; the labels are in a different order for each overlay. In tactile mode, each button of the top three rows corresponds to one of 21 shapes. The rows of the keyboard are connected to the outputs of a latch, which is driven by four microprocessor data bits. The columns of the keyboard are connected to seven of the inputs of a latch, which is read by the microprocessor.

The processing unit consists of a Z180 microprocessor on the Smartcore Z1 Board (Zworld Engineering, Davis, CA). The switch values are latched and read by the microprocessor to determine the mode and the overlay. After determining the mode, the microprocessor activates the voice chips, which play messages such as "Can you find the fuzzy ball?" (in tactile mode) or "Can you spell the word dog?" (in spelling mode). The microprocessor then latches one of the rows of the keyboard high while holding the others low and scans the keyboard to identify whether or not the correct button(s) is pushed. The processor then scans the columns to see if any of the buttons are pushed. If no button is pushed, the processor latches the next row high and scans the columns again. This process continues until a pushed button is located, and then a buzzer is sounded to indicate to the child that a push has been registered. Once the key location has been determined, the processor ensures that the key has been released before registering another key value. In addition, the processor checks to make sure two buttons are not pushed at once. If more than one button is being pushed, it waits until only one button is actuated.

Four ISD90 (Information Storage Devices, San Jose, CA) 90-second voice chips store messages, including 200 spelling words, 21 object names, and a few phrases. The microprocessor accesses the recordings using the address lines of the voice chips. To send a specific message, the processor transmits the address of the message to the voice chip using its data lines. Because the voice chip has 10 address lines, while the microprocessor has only eight data lines, two of the address lines on the processor are used along with the data lines to address the voice chips. Two other address lines are used to select which voice chip will be turned on. This minimizes power consumption since three of the four voice chips are in standby mode at all times. When a voice chip is selected, its output to the speaker is enabled using a relay.

The final cost of the spelling and tactile identification game is approximately $540.

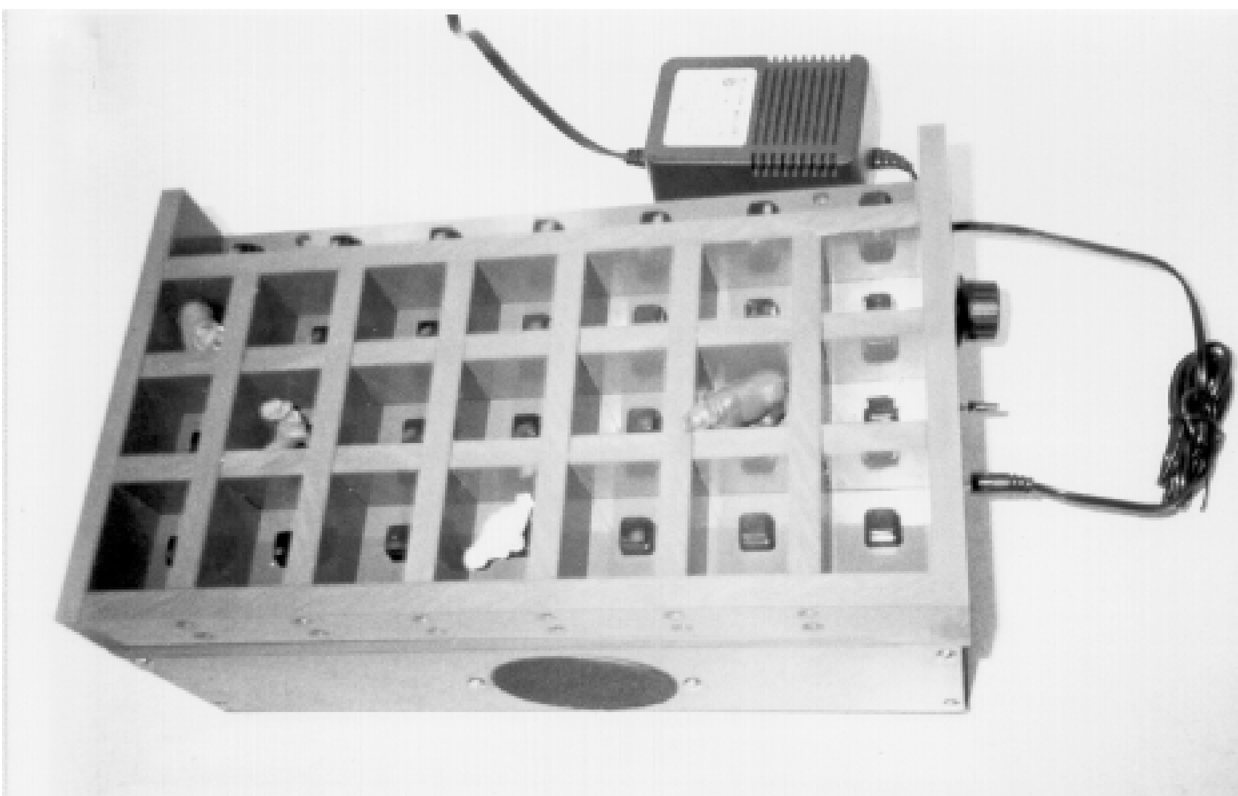

Figure 5.4. Spelling and Tactile Identification Game in Tactile Mode.