CHAPTER 6
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ORTHOPEDIC DRIVING SIMULATOR

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INTRODUCTION
An orthopedic driving simulator was designed to aid in evaluating the driving ability of individuals who have undergone orthopedic surgery of the hip or knee.

SUMMARY OF IMPACT
The orthopedic driving simulator replicates driving environments to assess functional recovery for driving after orthopedic surgery, such as total hip or total knee replacements. It provides physicians and researchers a realistic method of evaluating a person’s driving ability. This is important in making an informed decision about the driving safety of a given individual before he or she is permitted to drive.

TECHNICAL DESCRIPTION
The concept design for this device is shown in Figure 6.1. The system, shown in Figure 6.2, consists of a chair, a pedal with force transducer and a computer. Upon an event (red light), the patient is to brake as soon as possible with a force he or she judges to be necessary. The braking time and force are recorded and displayed.

![Fig. 6.1. Orthopedic Driving Simulator Concept Design.](image-url)
Fig. 6.2 (a) Prototype Design. (b) Details of the Foot Pedal.
MANUALLY CONTROLLED HIP ORTHOSIS

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INTRODUCTION
Hip Orthosis is used extensively in physical therapy, orthopedics, and in the orthotics industry to provide support of the hip joint on one or both sides of the patient’s body. Hip orthosis is used by patients with normal hip flexors, who have the capability of flexing their hips manually when the gait cycle is initiated. If a patient has weak hip flexors, his or her only option is to have very limited gait or to be confined to a wheelchair. The current technology for hip orthosis involves very limited assistance in gait such as the Reciprocating Gait Orthoses, the general Hip Orthosis, and the Standing-Walking and Sitting Hip Orthosis (S.W.A.S.H) used primarily by infants and children. There is a need to develop a manually controlled hip orthotics for patients with weak hip flexors.

SUMMARY OF IMPACT
The aim of this project was to provide a manually controlled hip orthosis that will manually flex the hip when a lever is pulled to initiate the gait cycle. This information will be directed toward patients who have had a stroke and have paralysis on one side of the body along with mild cases of muscular dystrophy and multiple sclerosis. Future iterations of this device will include the ability to provide manually controlled hip orthoses for patients with weakness in both hips. The design is versatile, flexible and low-cost. Materials chosen are common and the technology is easily attainable. Quality and customer satisfaction were important in the design of this product.

TECHNICAL DESCRIPTION
Specifications were based on customer suggestions and needs. Important design considerations were the location of the lever, the required force needed to pull the lever and flex the hip, and the configuration of the spring around the total hip replacement joint. It was decided that the force required to push the button to release the gear tooth and manually flex the hip should be under 1 pound, the required force to flex the hip being 60 pounds, and the configuration of the spring being a flat spring in the cantilever spring/beam configuration with point load at extreme end. Based on customer and manufacturing needs, it was decided that offering a flat spring in cantilever beam formation would be the most flexible and effective option. The prototype is shown in Figure 6.3.
Fig. 6.3. Prototype.
INTRODUCTION
Repetitive exercises have been shown to help rewire damaged nerves. According to personal interviews with occupational therapists (OTs) and physical therapists (PTs), supination and pronation movements are critical to recovery. However, most exercise equipment designed to focus on such movements does not provide feedback to motivate users. Some computerized devices do provide feedback but are too expensive for many clinics and individual users.

SUMMARY OF IMPACT
The neuro-rehab game, shown in Figures 6.6 and 6.7, was designed to provide motivation for stroke survivors during exercise. The designer may turn this idea into a useable device that will meet FDA standards for a class I medical device 5370.

Fig. 6.4 (a and b). Design and Display of System for Practicing Grasping and Wrist Rotation.
TECHNICAL DESCRIPTION
The designer assessed customer needs and created metrics based on those needs that could be measured and evaluated for the product. Next, concepts were generated and taken through a selection process to select the best design for the neuro-rehab game. This process was followed by surveys to derive opinions from potential buyers. The results helped to select one design over the others. The designer continued with the selected concept and began selecting materials with the use of an analytical model. Also, a business plan was completed to summarize the efforts to date and propose future work. The testing of the prototype focused on functionality of the test and proved adequate in satisfying user expectations.

Fig. 6.5. Device in Use to Practice Wrist Rotation. Amount of Rotation Displayed on Screen.
INTRODUCTION
The goal was to design a low-cost, mechanical, Tremor Control Arm Brace that can be used by tremor patients when trying to perform certain activities. The client has a hereditary essential tremor.

DESCRIPTION OF IMPACT
This project represents a temporary means of reducing arm tremor. Other options are costly and invasive procedures such as deep brain stimulation, neurosurgery or medication. Rather than addressing neurological problems, this project focuses on a mechanical solution for use during short periods of time.

TECHNICAL DESCRIPTION
Design requirements were based on one client’s needs but are compatible with the needs of most patients with tremor.

The major design requirements were that the product effectively reduce tremor, allow for wrist rotation, have universal sizes, be lightweight, be simple to position around the arm (by the patient alone), and not be very noticeable. The most viable option, given time and budget constraints, was a hinged joint arm brace. The brace has a clamping mechanism in both the upper arm and lower arm.
with variable pressure settings. These clamps are connected to a stiff bar that includes a lockable joint at the level of the elbow. This joint will allow for movement in flexion and extension while offering the possibility to lock at a certain angle for specific activities such as lifting or pushing. The combination of the arm bar and the arm clamps will offer the necessary resistance to control the tremor. The device is illustrated in Figures 6.6 and 6.7.

Testing was performed on a 3D modeling system called ViconPeak in order to model tremor. An analytical prototype of the Tremor Control Arm Brace has been created and tested in SolidWorks. This design has resisted a pressure of 15 N and passed all stress and displacement tests to effectively reduce tremor. A physical prototype is currently under construction. Future work will include testing this prototype with the ViconPeak system to compare past tremor data with conditions under the effect of the Tremor Control Arm Brace.
ARM REHABILITATION GAME

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Design Mentor: Ed Koeneman, Kinetic Muscles Incorporated
Project Coordinator: Dr. Vincent Pizziconi
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INTRODUCTION
A goal of this project was to design a fun and interactive rehabilitation system that incorporates repetitive exercise to enhance arm mobility.

SUMMARY OF IMPACT
This fun and interactive tabletop game, shown in Figure 6.8, incorporates useful arm movements for rehabilitation of patients with limited mobility due to stroke. It reduces the monotony of repetitive exercise. It is the hope of the designer that the arm

Fig. 6.8. Arm Rehabilitation Tabletop Game.
rehabilitation game will reduce the cost of therapy and reduce the monotony of the repetitive movements in neurological stroke rehabilitation.

**TECHNICAL DESCRIPTION**

A House of Quality was constructed, detailing the vital design information, including customer needs, product metrics and product specifications. Mathematical models were also created to ensure the technical merit of the product design. The Arm Rehabilitation Tabletop (ART) Game, shown in Fig. 6.8, incorporates three main movements for the patient: reaching straight ahead, reaching up and away from the body, and rotating. The device is adjustable according to patient ability, amount of spasticity or tightness of the limbs. Each movement corresponds to a movement for which multiple repetitions have been shown to stimulate brain plasticity. The game provides timing feedback and a scoring system to keep the patient motivated and to provide a sense of competition. The ART Game is classified as an exempt Class 1 device according to the FDA Center for Devices and Radiological Health. No pre-market notification will be required. A cost model was created by determining the necessary components for the game and the cost of manufacturing. The 1-3-9 rule was modified to 1-4-5 and applied to the device. The designer will continue to work on ways to reduce the cost of the device by searching for less expensive components and manufacturing methods.

The estimate of the total retail cost of the device is $507.

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Fig. 6.9. Illustration how the game will be used for rehabilitation
INTRODUCTION
The Magnetic Resonance (MR) Compatible Hand Diagnostic Device is a diagnostic research tool for use on patients who have had a stroke affecting mobility in the left or right hand. The device is designed to be used during a functional magnetic resonance image (fMRI) to allow the motion of the affected hand to be mapped to the brain. The device is non-magnetic and uses a pneumatic air-muscle and angle sensor to measure the range of motion and force produced by the hand and wrist during flexion and extension. The device will allow variable resistance to be applied to resist hand flexion and therefore provide more information about the ability of the hand. The motion of the hand is monitored on
a computer outside the MRI room. The device also provides a method for immobilizing the arm during the MRI to allow for minimal image artifact. Through research using the MR Compatible Hand Diagnostic Device, the changes in the brain over a rehabilitation period can be mapped to the increasing mobility of the hand. Advancement in this area of neurological rehabilitation research has the potential to reach the millions of people living with the effects of stroke.

SUMMARY OF IMPACT
The design goal was to make a diagnostic tool for the hand that is fMRI compatible and universal to all stroke patients. The design process followed the Food and Drug Administration’s (FDA) Quality System Requirements (QSR) by developing design inputs and outputs and validating that the design outputs adequately met the design requirements.

The primary market for this device is neurological research institutions and research hospitals.

TECHNICAL DESCRIPTION
Customer surveys were used to gather design input. An extensive concept testing and selection process was used to select the design of this device. The product was designed, prototyped and tested. It is shown in Figures 6.10 and 6.11.

To optimize the device for manufacture, a cost model was generated which includes estimates for standard and custom components, processing, assembly, and overhead – yielding an approximate unit cost of $177. Based on the manufacturing cost of this device, the retail price is expected to be $1,400, which is reasonable for the market consumers at research hospitals and universities and other research institutions.

Fig. 6.11. MR Compatible Hand Diagnostic Device.
TRANSFERRING WHEELCHAIR

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INTRODUCTION
The objective of this biomedical device was to assist with the transfer of people from a wheelchair to a stationary object such as a bed. This device is based on the design of the basic wheelchair and includes variations of that design in order to accomplish the purpose of the device.

SUMMARY OF IMPACT
For many, the wheelchair transfer process is difficult and cumbersome, as well as painful. It affects those using a wheelchair and those assisting with this process. This new wheelchair design includes new features that will aid with the transfer process. These include: 1) reclining seatback of chair; 2) extra supports for stability in the reclined position; and 3) sliding seat and seatback to facilitate moving from chair to object.

TECHNICAL DESCRIPTION
This is a medical device design and thus would be under the jurisdiction of the Food and Drug Administration. Design and manufacture must meet quality standards of viability, safety, and effective design. The design controls consist of such areas as: design input, design output, design transfer, design verification, and validation, and the manufacturing processes. From these procedures the final product specifications have been established, and the final prototype has been created and tested. It is shown in Figure 6.12.
Fig. 6.12. Wheelchair in Transferring Position.
HIP-KNEE MENTOR

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INTRODUCTION

Many stroke survivors have a loss of some degree of motor control. If the lower extremities are affected, gait may be limited and the ability to perform routine tasks may be reduced. There is a need for a device to help rehabilitate hip and knee movement.

SUMMARY OF IMPACT

The device in development for this need is dubbed the Hip-Knee Mentor. The purpose is to retrain the brain, through repetitive motion, to potentially establish new neural pathways in order to recover lost motor control in both the hip and knee.

TECHNICAL DESCRIPTION

The Hip-Knee Mentor, shown in Figures 6.12 and 6.13, was designed to help patients regain hip and knee motion. Once the mentor is put around the waist, it uses force to move the patient’s hip and knee. The patient is expected to focus on the hip and knee movement, thus forcing the brain to associate the function with the movement of the hip and knee. Such a device will be used for years on a daily basis for several hours a day. In certain cases, the brain will not be able to relearn the motion, depending on the age of the patient, and the extent of brain damage.

In the long term, the brain is expected to rewire neural pathways, thus creating new hip and knee flexion and extension functions. It is not reasonable to assume that the patient will have the same hip and knee control that he or she had before the accident, but it is reasonable to expect that the patient will be able to move his or her hip and knee, which is more beneficial than not being able to move them at all.
Fig. 6.14. Hip-Knee Mentor Helps a Person Flex the Knee and Hip Joints.
NSF 2006 Engineering Senior Design Projects to Aid Persons with Disabilities