ENGR 140

Team 8: Nicha Thongtanakul and Charles Rockhead
technical paper

1. **Design Selection**

Case requirement

A device is required to help promote rehabilitation of stroke patients with upper arm impairments. An end effector is required to measure rotation of a shaft, which will be turned by patients. The measured position should be communicated to a unity-based game which allows for building hand eye coordination. This device must be durable, easily manufactured and managed while keeping costs low. The main patient priority is to build grip and extremity strength through extensive use of this device. It is also required that the unity based game be interfaced with existing robotic hardware, so we intend to develop a similar rotating shaft used as the main interface for patients and the game.

State of the art

Currently, there are numerous amounts of technologies and design concepts, which exist to aid in rehabilitation of stroke patients. A description of some of the existing state of the art devices will be provided .

- ● The Design C.A.R.E.S, which stands for Community-based Affordable exercising system, is an example of a state of the art system, which focuses on stroke patient rehabilitation using low cost technology. The design incorporates 3 stations of interactive digital rehabilitation systems, which encapsulate severe patient injuries unlike those of commercial devices and games such as Wii, Nintendo Gamecube. One of these stations is the arm-lever driven Theradrive, which has sensors reporting the position. A game used with this device is a tracking task where one must stay within a certain range of an approaching path outlined on the screen. There are 2 modes to this: One where the robot guides the arm movement, and one where the patient does the work. Resistance is adjustable. An advantage is that its cost effectiveness allows the device to be available to a larger quantity of people as it lessens the factor of affordability in patient treatment. However, a disadvantage of the system is that in its current stage it is not as visually engaging and the patient-interface interaction system is two-dimensional.
- ● The Armeo therapy concept is also an existing state of the art design, which aims to serve as a rehabilitation medium for individuals who have suffered strokes, traumatic brain injury or neurological disorders resulting in hand and arm impairment. Its design is centered around neuroplasticity where intensive rehabilitative tasks are done repeatedly in order to facilitate the gradual movement and functionality of injured areas by reorganization of the brain's neural network allowing it to be more accustomed to completing those tasks. It also allows for the physiotherapist to not be present throughout treatment, which saves patient costs. An example of this would be the Armeo Senso, which uses a wireless system, including a hand module and 3 sensors, to monitor movements. This technology is particularly impressive in its gaming graphics, which incorporates the use of augmented reality in order to stimulate continued patient engagement with the device. These systems seem to still be mainly in conceptual design and not yet fully commercially available. A disadvantage would likely be the price as

many of the technologies described are very expensive, and so less patients will be able to afford the treatment

Design opportunity

The case calls for a unity-based game, which would involve the development of new software to interface with the existing robotic technology we currently have available in both Philadelphia and Kingston. We believe the existing games used with the Theradrive have yet to be fully developed. Upon visiting the lab, we were able to see the tracking game in action. At this stage the games seem simplistic and unexciting, primarily serving the purpose of rehabilitation. With the tracking task, there is a clear goal, but minimal elements of surprise, interaction, or strategy to keep the player engaged. There is also no human interaction between the patient and his or her caregiver or other patients during the course of the game, when cooperative elements could be incorporated. We are focusing on this lack of patient engagement as an opportunity to design a game that would hide the clinical aspect and make the rehabilitation process fun and enjoyable. We could also add in features specific to the Jamaican culture to make rehabilitation a more familiar and special experience for our patients. We hope that the implementations of our game will cause patients to look forward to therapy sessions as one might to a trip to the arcade. We will also design hardware to complement the new software, and facilitate the interactive experience. We hope that this would motivate patients to use the machine more and speed up and improve their recovery.

Brainstorming process

The brainstorming process was done as a group via skype. Various concept designs were generated, which were screened using a Pugh chart. The requirements of the matrix were chosen based on the HAAT Model and, a reference point (datum) was chosen to be the Theradrive currently found at UPenn. The various ideas generated were giving a relative rank depending on how well it stacked up against the datum chosen. The concepts that fell below a given rank were discarded after careful deliberation by the team. The remaining concepts were then scored by creating a weighted decision matrix. Weightings were assigned to the individual requirements and the encoding scheme used for the performance ratings of the requirements was converted into numbers ranging from 1-5. These numbers multiplied with the weightings produced the weighted score, which was then summed to give the total score of the concept. The scores were then ranked from highest to lowest revealing the ranking of each concept.

Description and evaluation of concepts

All of the following should have the same safety features as the Theradrive currently has eg. emergency stop.
They would also ideally all record the position of the lever and the force applied on the pressure ball (if present).

1. Driving Simulator: This would use a Steering wheel with force feedback: a driving simulator interface which uses a force-feedback split-steering wheel with a force sensor for each hand that enables the robot to respond differently to force inputs from each hand. For example, the robot resists forces applied by a stroke patient's unimpaired arm, forcing the patient to use the impaired arm to assist in the completion of steering tasks. There could be cars driving in the opposite direction in which the patient would use the steering wheel to avoid each car. The resistance of the steering as well as the speed of

each oncoming car can be adjusted. There could also be two game modes i.e. a one handed and two handed game mode. There could be a multiplayer mode where people race against each other. This concept explores the idea of simple meets universal. We have adapted a regular arcade game to be more comprehensive in functionality, yet still maintain the simplistic of any arcade driving game.

2. Bobsled simulator: This is a popular Jamaican sport. Similar to the driving simulator however instead of avoiding oncoming cars, there would be pressure plates on the side of the patient to apply steering in the bobsled so it doesn't fall out the track. Also objects could in front of the bobsled as moves along the track in order to increase difficulty and more pressure could be needed as the patient develops their strength. There would also be a force feedback to notify the player if more force is required. There could be a multiplayer mode where people race against each other.
3. Rhythm game: This would be an adapted form of Dance Dance Revolution. It could come with a tutorial that used the famous Jamaican song ‘No woman no cry’. The other song choices could also be popular Jamaican music, or any music in general. Potentially AI could create the steps to any song given enough time for software development. The Theradrive arm lever would interfaced with rod to allow optional bilateral movement to control the game. As with DDR, arrows fall down to the bottom of the screen according to the beat of the music. With this game, it will be simplified to left and right arrows. Players should move the lever so that it is within a certain angle range at the right time. There could be a multiplayer mode where people compete against each other using the same song. This concept addresses the idea of fashion meets discretion, more closely the discretion side of it. If this game were to be played in public e.g. a park, arcade, it would attract attention and not at all in a negative way. It could be a source of entertainment, an invitation to dance.
4. Dandy Shandy: This activity is unique to Jamaican culture. A stress ball with an integrate pressure sensor attached to the Theradrive. The device is based on the popular local game referred to as ‘Dandy Shandy’ where people would throw light makeshift objects at each other in a similar fashion to dodgeball. The user could play against other players or with a bot. This concept deals identity meets ability, since we can pair up players at similar or different points in recovery, the players will only move as fast and squeeze as strong they are capable. These 2 actions can compensate for one another in a compromise unique to each player.
5. Juggling football: The Theradrive would be interfaced with a ball handle with a pressure sensor inside. The game would simulate a foot juggle. The arm lever would control the position of the foot on the screen, and the ball handle when squeezed could control the power of the kick. The game could have 2 modes: free juggle and guided juggle. In the free juggle version, the player could freely juggle the ball back and forth. In the guided juggle version, the player would have to try to match the position of a virtual outline, and squeeze when the foot starts kicking up (reflex time). There could also be an automatic mode like in the tracking task of the Theradrive, where by the player’s arm is guided.
6. Biking simulator: The arm level would be interfaced with a rod designed to be held in both hands and cranked back and forth, the speed of the cranking would determine the speed of the ascent up the hill. There could be a speedometer icon in the corner of the screen. As mentioned in the sketch, the game could have a variety of modes in different locations, with different threats for falling behind like the rolling calf. Assisted and unassisted modes.


1
display
3
display showing arrow sequences
scalable pressure sensed mat
5
display
theradrive
2
pressure sensors to help +/- steering bobs sled
6
4
pressurized
voice feed back stress ball
theradrive
Dandy shandy simulator

Concept selection:

HAAT requirements	priority rank
Structure durability	2
Low cost	1
Ease of manufacturability	3
Easily assembled	3
Effectively builds hand eye coordination	1
Builds grip strength-finger/palm	1
Builds extremity strength	1
ease of use	2
ease of maintenance	2
Cost of operation	3
safety	1
quality of feedback medical	2
patient comfort	2
Game has clear, interesting goal	1
Good incorporation of game elements: surprise, strategy	1
potential interaction between the patients during game	1
Good incorporation of jamaican culture	2

We have chosen to move forward with only requirements ranked 1 and 2. Pugh selection: +s are indicated by 1; -s indicated by -1

requirements	state of the art		ideas					
	theradrive	armeo senso	driving	bobsled	rhythm game	Dandy Shandy	juggling	bicycle simulator
Structure durability	0	-1	0	0	0	0	0	0
Low cost	0	-1	-1	-1	0	0	0	0
Effectively builds hand eye coordination	0	1	1	1	0	1	1	0
Builds grip strength-finger/palm	0	1	0	0	0	1	1	0
Builds extremity strength	0	1	1	1	0	1	1	0
ease of use	0	-1	1	1	0	-1	-1	0
ease of maintenance	0	-1	0	0	0	-1	-1	0
safety	0	0	0	0	0	0	0	0
quality of feedback medical	0	1	1	1	1	1	1	1

patient comfort	0	0	1	1	0	0	0	0
Game has clear, interesting goal	0	1	1	1	1	1	1	0
Good incorporation of game elements: surprise, strategy	0	1	1	1	1	1	1	0
potential interaction between the patients during game	0	1	1	1	1	1	0	0
Good incorporation of jamaican culture	0	0	0	1	0	1	1	0
pluses	0	7	8	9	4	8	7	1
minuses	0	4	1	1	0	2	2	0
net	0	3	7	8	4	6	5	1
rank			2	1	5	3	4	6
continue?			Y	Y	N	Y	Y	N

Conclusions:

We can see from here that the driving and bobsled ideas are identical in features basically, apart from the driving one missing the Jamaican aspect of culture. Since they are so similar, we have decided to combine them and just move with the bobsled idea. This idea still uses a steering wheel with force feedback, so it will be possible to add a driving mode should we have time. The third best idea we have and Dandy Shandy. We could improve the ease of use of the Dandy Shandy by adding a tutorial program to the software. We agreed that the rhythm game and the bicycle simulator did not offer much in terms of exciting additional functionality to the Theradrive as it is, since they both only involve the additional rod interface. In fourth place, the juggling game seems not as interactive as the other games, but this could be very different if we added a mode where players could pass the ball to each other.

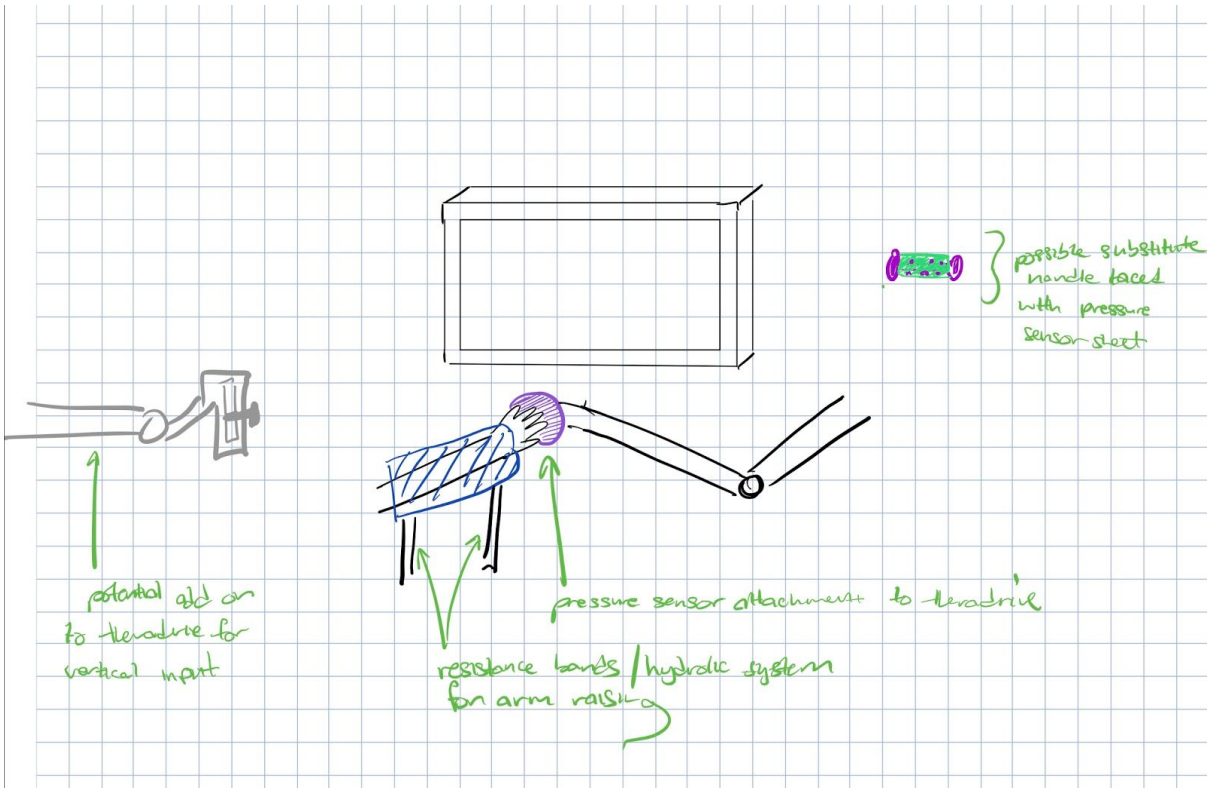
Weighted selection

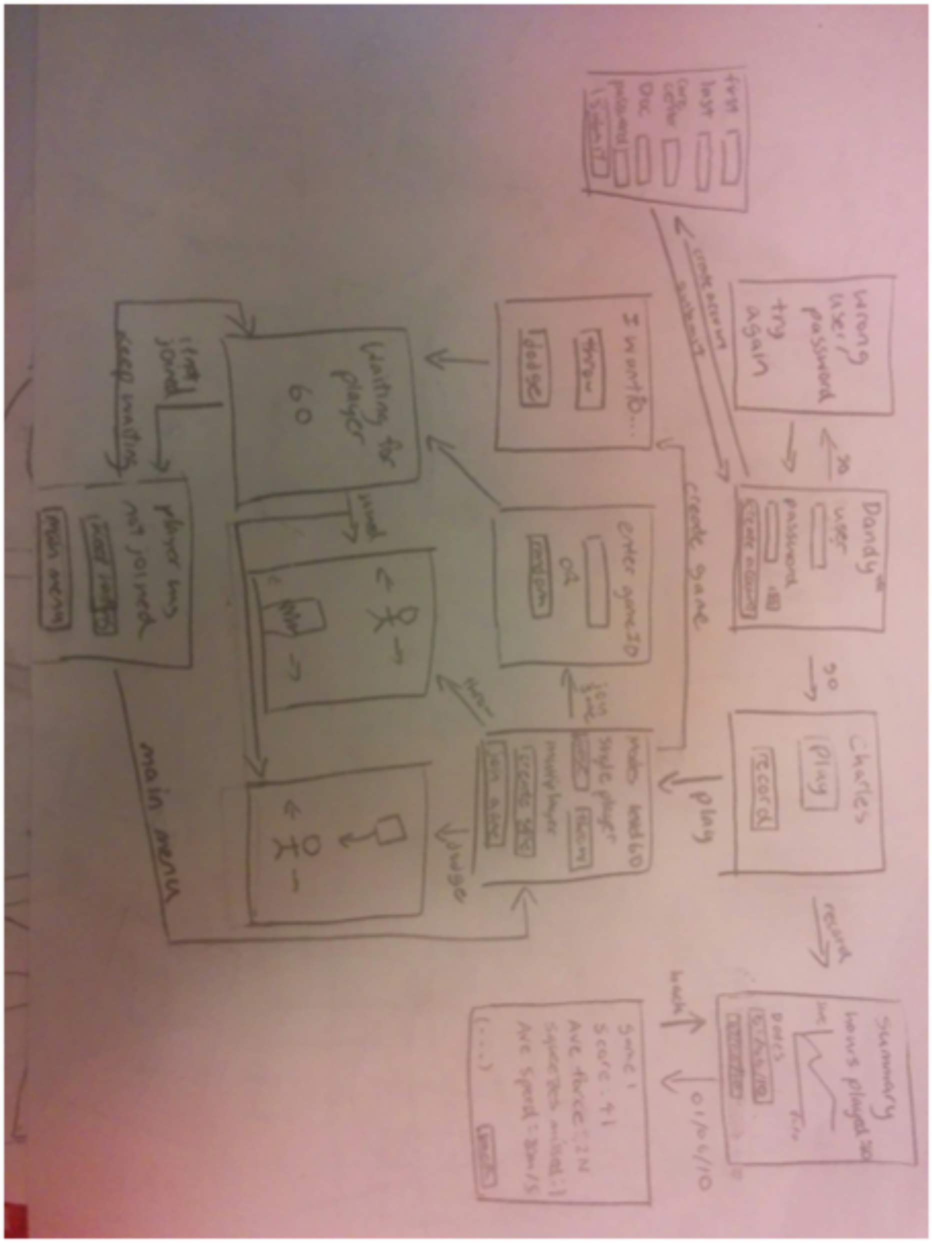
Weighting: priority 1: 0.0875; priority 2: 0.05 Scores: -- 1; - 2; neutral 3; + 4; ++ 5
Ref value of score 3 chosen for each requirement.

			bobsled		Dandy Shandy		juggling	
requirements	priorities	weighting	score	score*weighting	score	score*weighting	score	score*weighting
Low cost	1	0.0875	2	0.175	3	0.2625	3	0.2625
Effectively builds hand eye coordination	1	0.0875	2	0.175	3	0.2625	2	0.175
Builds grip strength-finger/palm	1	0.0875	2	0.175	3	0.2625	3	0.2625
Builds extremity strength	1	0.0875	3	0.2625	3	0.2625	3	0.2625
safety	1	0.0875	2	0.175	3	0.2625	3	0.2625
Game has clear, interesting goal	1	0.0875	3	0.2625	3	0.2625	2	0.175
Good incorporation of game elements: surprise, strategy	1	0.0875	3	0.2625	3	0.2625	1	0.0875
potential interaction between the patients during game	1	0.0875	3	0.2625	3	0.2625	1	0.0875
Structure durability	2	0.05	3	0.15	2	0.1	2	0.1
ease of use	2	0.05	3	0.15	2	0.1	2	0.1
ease of maintenance	2	0.05	3	0.15	2	0.1	2	0.1
quality of feedback medical	2	0.05	3	0.15	3	0.15	2	0.1
patient comfort	2	0.05	3	0.15	3	0.15	3	0.15
Good incorporation of jamaican culture	2	0.05	3	0.15	3	0.15	2	0.1
total score				2.65	39	2.85	31	2.225
rank				2		1		3
continue?				Y		Y		N

Conclusion: We have narrowed it down to the bobsled and Dandy Shandy. We could have incorporated additional features to the bobsled such as brakes, so that players also get to exercise grip strength. However, we decided to go forward with Dandy Shandy, because it is more unique to the Jamaican culture. The game definitely satisfies our priorities, with a clear, interesting goal and a definite platform for motivating patient-patient interaction.

2. ***Sketch-Device; Software interface***




Wrong user/password
try again
Dandy
user
password
Charles
play
record
create game
create account
Waiting for player
60
enter gameID
player has not joined
keep waiting
main menu
pause
summary
hours played
back

3) **Storyboard**

4a) **Design feasibility case**

Design feasibility refers to the logistics of implementing this design relative to existing designs as well as the functionality of our device. The existing designs for rehabilitation that are present at the Sir John Golding rehabilitation center include treadmills, stationary bikes, and other basic exercise equipment. At the University of Technology in Jamaica, there is a copy of the Theradrive machine that exists in the lab in Philadelphia. The Theradrive is a rehabilitative robot that helps with hand eye coordination of patients by allowing the user to control a handle and keep it on track of the displayed path in the tracking game. The Theradrive contains force sensors that detect when to provide assistive movement for patients struggling to move the Theradrive arm. However, this machine does not aid in the rehabilitation of patients who want to improve their grip strength. Our end effector design will integrate a relatively cheap differential pressure sensor system and bulb to be squeezed by the patient. The pressure readings will be proportional to the patient grip strength. By calibrating a starting threshold pressure for some action in our game to an individual patient and increasing it over time, we intend to improve his grip function over time.

Besides those functionalities, the display is not very interactive with the patient and is a very basic white and black screen, which may be boring to the patient. Our design is feasible in regard to the interactive aspect as it builds upon the cultural context of the machine as it encapsulates a popular Jamaican pass time (Dandy Shandy). Also our intended device embraces the existing beneficial elements of the Theradrive such as its ease of manufacturing, and affordable price point. We intend on simply attaching the end effector into existing circuitry on the Theradrive. This will be relatively cheap to do.

We note that although it was our original plan to implement the Dandy Shandy, this changed after talking to our patient, Denzel, during our trip to Jamaica. Denzel was much more enthusiastic about a game called Space Invaders, and we managed to adapt to this new information on short notice. All other aspects of the design remain identical, including the design of the end effector. The position of the throwing arm in Dandy Shandy was to be controlled by reading the angle of the Theradrive arm much like in the tracking device game. The squeeze of the pressure-sensing bulb was would trigger the throwing of the projectile juice box toward a target dodger. Similarly, in Space Invaders the position of the player would be controlled by the angle of the Theradrive arm, and squeezes of the bulb would correspond to shots at the invading aliens.

5b) **User benefit case**

Our design is not based on a specific patient but rather a general category of patients that require rehabilitation of upper arms, grip strength and hand eye coordination. Physically, it will benefit the user by improving the muscular strength and usability of their arms and hands allowing them to expand the variety of actions they are able to do and tools they can manipulate. As a result, this general category of patients will be able to become more independent and do more daily living tasks such as brushing their own teeth, dressing themselves or assisting with the dressing process and eating on their own.

3-6 months after a stroke, the majority of stroke survivors stop improving. This can be due to many reasons, such as insurance or boredom with repetitive tasks. However, research shows patients can improve even after this timespan. Our game addresses the problem of boredom. Mentally, patients will gain from the fun and entertainment of the game, and a more interactive

rehabilitation experience. They will be more motivated and hopefully be more willing to practice a larger number of repetitions. The robot will allow more repetitions to be practiced without the direct guidance of a clinician, leading to a faster recovery. After interviewing our patient, Denzel, we confirmed that no games were being used at Sir John Golding. Thus, the introduction of this device to the center would be a large benefit to all the patients who currently undergo treatment there.

The design will benefit the user's family as they may now reduce their investment into the patient's care, whether that is monetary through the hiring of a nurse or rehabilitation course, or time wise.

Additionally, this is beneficial to the institution as the machine should be able to allow the patient to undergo rehabilitation with minimal or no involvement of a caretaker or clinician. This will allow time efficiency (more patients to be treated at once) as well as reduce costs for the institution. For places such as Kingston Public Hospital, this is very important. They have only 9 physiotherapists to treat over 100 patients a day. The system will also allow automated data collection and more data such as grip force to be collected to better monitor the rehabilitation of the patients. Introducing a robot to guide patient movement will standardize treatment across clinicians and reduce variability in repetitions conducted by the same physician, leading to a more consistent rehabilitation process for all patients.

This is also beneficial for the clinician, as they are able to more carefully focus on the patient movement as the patient is guided by the robot, and not by the clinician themselves. This also means that sessions are less strenuous on the clinician, since they do not have to physically guide patient movement for multiple repetitions.

5a) **Prototypes and Final Design**

See videos attached

Prototype 1: A proxy involving a continuous measurement reading with a threshold that triggers an action. Using an ultrasonic sensor as a proxy for a pressure sensor. A threshold of 20cm was set in place of a pressure threshold. When the distance between the sensor and a panel is 20cm (or less), an LED bulb lights up. This LED is a proxy for the action of shooting in the game Space Invaders.

Prototype 2: Prototyping the end effector. Demonstrating the pressure sensor works using 1) a pipette embedded in a stress ball and 2) a blood pressure bulb. Upon squeezing, we can see the peaks in the Arduino serial plotter.

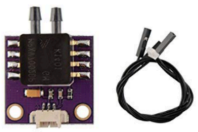
Prototype 3: Interfacing the end effector with Space Invaders. We successfully read in pressure data from the Arduino to the unity platform. Video captures Denzel's first interaction with the game. Here, we had not yet calibrated the pressure threshold to his needs, and the pressure threshold was too high for Denzel to successfully trigger a shot. At the end of the clip, we see that his arm displays spasticity.

Final prototype: Game and end effector completely interfaced with pressure threshold set for Denzel's needs. User movement of Theradrive arm angle controls horizontal movement of

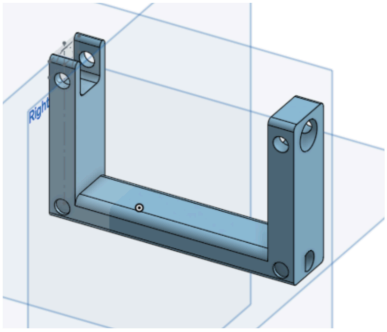
shooter across screen. Shooting is triggered upon user squeezing the bulb pass a certain pressure threshold.

End effector design:

The design simply consisted of the following 4 parts.



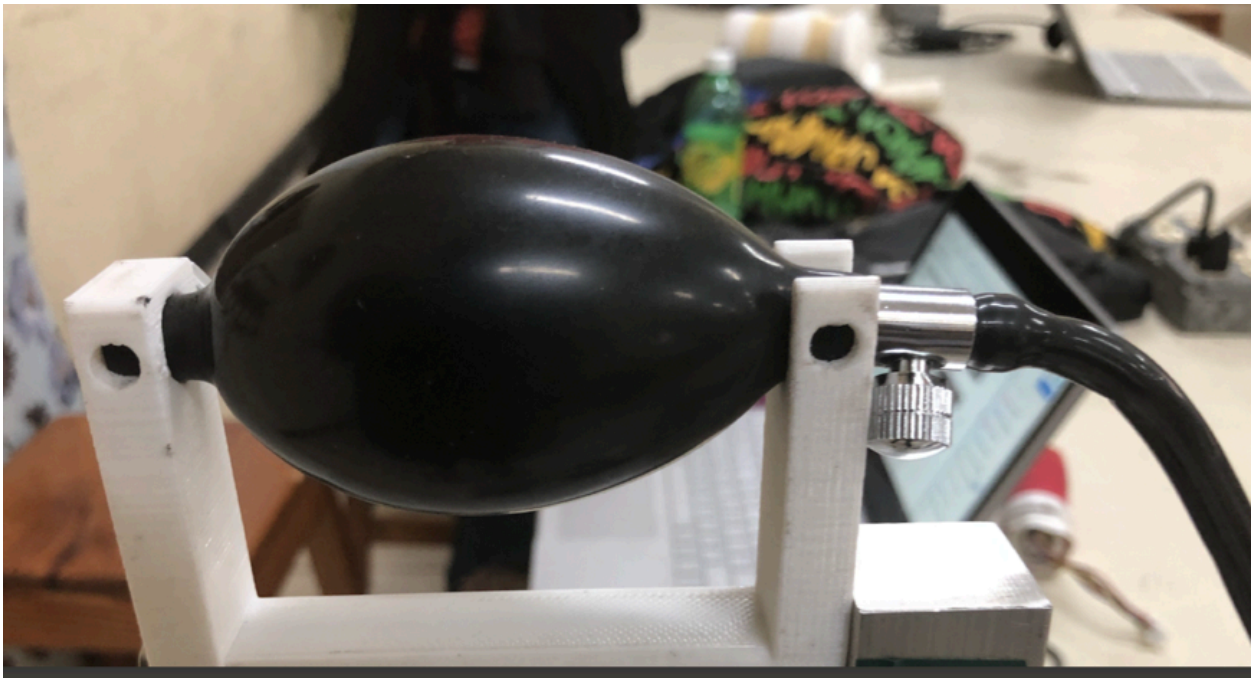
Diymore Breakout Board MPXV7002DP Transducer APM2.5 APM2.52 Differential Pressure Sensor
by diymore
20 customer reviews | 14 answered questions
Price: $16.50 prime
Style: MPXV7002DP



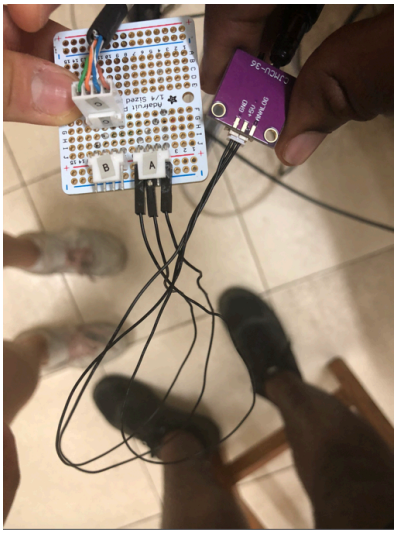
by FOLAI
Blood Pressure Bulb Pump Replacement with Tubing Rubber Adjustable Pump Bulb rubber blood tester for Sphygmomanometer
12 customer reviews
Amazon's Choice for "blood pressure pump"
Price: $9.99 prime
New (1) from $9.99 prime

by KINGLAKE
KINGLAKE Plastic Transfer Pipettes 3ML,Essential Oils Pipettes,Graduated,Pack of 100, Makeup Tool
318 customer reviews | 22 answered questions
Amazon's Choice for "pipette"
Price: $6.99 ($34.95 / Ounce) prime
New (1) from $6.99 prime

The end effector is easily replaces the original grip on the theradrive since it fits the same D-rod shaft.



Wiring Schematic:



How it looks like on the theradrive:

b/d) **Clinician Surveys**

No clinician input through our design process. After our final presentation, we tried contacting the head clinician at Sir John Golding Dr. Susan Henry to complete the clinician survey, but we received no response.

Below is that survey.

Satisfaction survey for clinician

1.Have you heard of robotic applications to physical therapy?
□ yes
□ no

2.Do you think the patient would benefit from the application of robotics to treatment?
□ strongly disagree
□ disagree
□ neutral
□agree
□strongly agree

3.Do you believe that improving grip strength would increase the quality of life of patients?
□ yes
□ no

4. To what extent do you think a device that measure the pressure applied to a ball would be an effective indicator of grip strength?
□ strongly disagree
□ disagree
□ neutral
□agree
□strongly agree

5.Do you believe the device is effectively developing grip strength for stroke patients if the pressure requirement increases over time?
□ yes
□ no

6. What do you think would be a sufficient allotted time for treatment?
_____ minutes every _____ days

7.Do you think the patient would benefit from the application of robotics to patients treatment?
□ yes
□ no

8. Do you think this device is cost effective to patients?
□ yes
□ no

9. What are ways do you think the device could be more accessible?
_____
_____
_____

10 Do you think this device would be easily incorporated in your therapy treatment schedule?
□ yes

□ no

11. Do you think there is an increase in the motivation and attitude of patients towards rehabilitation?
□ yes

□ no

c) **Patient Surveys**

Pre Survey

1. Are commercial games used for upper limb prosthetic rehabilitation in your facility?

□ Yes

☑ No

2. If yes, what 'games' are played at your facility?

_____

3. To the best of your knowledge, how many hours per week do you spend on rehabilitation for a specific target area?

□ <1 hour per week

☑ 1-3 hours per week

□ 4-6 hours per week

□ 6+ hours per week

□ Varies considerably depending on client

4. How important is it for you to have fun while you undergo rehabilitation?

☑very important

□ somewhat important

□ indifferent

□not really important

□not relevant at all

5. Do you think that having a digital game would improve your patient experience?

□ strongly disagree

□ disagree

□ neutral

□agree

✓strongly agree

6. Do you agree that games are more fun when they are culturally applicable?

□ strongly disagree

□ disagree

□ neutral

□agree

✓strongly agree

7. How many seconds are you able to squeeze the ball for?

10.12 seconds

8. How much pressure do you apply to the ball when you squeeze it as hard as you can?

1500 PA units

9. Do you experience spasms after you attempt to exercise your inflicted arm?

✓Yes

□ No

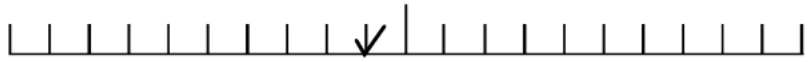
10. List 5 activities you would hope to accomplish after this grip strength targeting treatment?

I. turning a key
II. grasping objects
III. reaching
IV. driving
V. eating

Post Survey

Name	Task	Date
Denzel Jackson	Space Invaders	May 22

Mental Demand — How mentally demanding was the task?

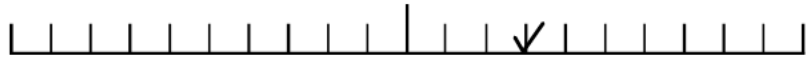


Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?



Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

1.To what extent, do you feel your grip strength has improved?

□ greatly improved

□ somewhat improved LONG TERM Q

□ neutral

□somewhat worsened

□greatly worsened

2.To what extent, do you agree that the patient enjoyed their experience?

□ strongly disagree

□ disagree

□ neutral

☑agree

□strongly agree

3.How many of the tasks are you now able to do the tasks that you desired to do?

_____/5 LONG TERM Q

4.To what extent do you agree that your quality of life improved?

□ strongly disagree

□ disagree

□ neutral LONG TERM Q

□agree

□strongly agree

5. Would you recommend this therapy treatment to others?

☑ Yes

□ No

6. What would you change or improve on this therapy treatment?

- wider ball holder for more comfort to squeeze ball, some support for the elbow

6) **Costs of Parts**

Part	Cost (USD)	Cost (JMD)
Pipette	0.07	133.89
Blood pressure bulb	9.99	1337.56
3D printed handle	1.00	133.89
Pressure transducer	16.50	2209.18
Total Cost	27.56	3690.01

VS JMD$535560.00 Armeo®Senso

7) **Jamaican market potential**

- Our design is cheap to produce as the software is the main component of this design and the design is not profit driven

- Our design is more engaging that existing models seen like the ones at KPH as they primarily consist of free weights and bicycle machines. These do not effectively engage or excite the patient and as a result our device would be more appealing to the public as it would make it feel less like rehabilitation.

- Our design targets various muscle groups simultaneously. This is unlike a lot of other machines available at the clinics we visited, which typically only target one muscle group such as biceps/triceps and don't combine exercises with hand eye coordination.

- Although the cost of Theradrive is relatively high, the above benefits in addition to the benefits of the use of robotics in rehabilitation outlined above, such as standardized rehabilitation and increased time efficiency, make the system a worthwhile investment.

8) Future improvements

- Develop more culturally relevant games that can better concert with the Jamaican clients such as scrimmage (equivalent of mini soccer), taxi driving, and track and field games.

- Movement assistance - Allow the Theradrive to guide the movement of the user's arm to help him get accustomed with the required motion for the task.

- Force feedback- If the patient's arm experiences fatigue, the Theradrive can assist him accordingly and proportionally to his level of weakness.

- Spasm detection- Develop a feedback mechanism that detects spasms based on the irregularity of his pressure readings. This detection would then allow the program to stop automatically and resume once the spasm has ceased.

9) Lessons Learnt

- Importance of client feedback- Meeting Denzel allowed us to learn more about the current treatment of stroke and traumatic brain injury in Jamaica. In addition, we were able to test and calibrate the game according to his feedback. For example, we had to adjust the threshold to suit his needs.

- Unpredictability of design changes- We did not anticipate changing the game until we met Denzel in Jamaica. It was worthwhile to change our design since we wanted to create the best experience for him.

- The power of learning by doing- Instead of spending more time writing about our designs, in Jamaica we went straight to work and learnt how to quickly prototype everything, which was a very valuable experience.

Acknowledgements

PGS – for facilitating the travel component of this course to allow students to develop and donate the stroke technology to patients

Staff – to the teachers and TA's who guided us on creating the tech and allowing us to learn from our mistakes and fix them in all dimensions allowing us to grow both as engineers and as people

Patients – for being the inspiration of our designs and allowing us to apply our knowledge by helping others and by being such kind-hearted and patient people

Fellow engineers and all those who facilitated this program – thank you for sharing this journey with us