Background

Over 795,000 people in America suffer from a stroke every year. While almost 20% of strokes are fatal, other times individuals are left with severe problems with their mobility. This has caused strokes to become the leading cause of long term disability. Problems can range from complete loss of mobility, to detrimental effects in muscle control and movement of limbs. Although most neurological damage is beyond repair, neuroplasticity has allowed the body to repair itself and compensate for the losses it endures.

Common treatment for patients who experience mobility problems is to go through rehabilitation programs aimed at helping them regain the highest level of mobility possible. The problem with these programs is that patients often lose interest and motivation due to the disengaging nature of the exercises and equipment. Therapists are challenged, and often unsuccessful, in finding creative ways to keep patients motivated. As patients discontinue their rehabilitation, their disabilities worsen lowering their quality of life while also putting a greater toll on the health care system.

Music to Movement (M2M) is addressing this problem by developing an assistive music therapy device to create a fun and engaging experience for patients working towards their recovery. Musical therapy not only aids a user's physical rehabilitation, but also improves emotional healing by gamifying the exercises to provide motivation to the user.

Alternative Solutions

During the initial stages of developing M2M, our team researched various designs for incorporating music therapy into physical rehabilitation and investigated a variety of target audiences that we believe would benefit from such technology. The potential audiences considered who would benefit from a music therapy device could include: Patients with Down Syndrome, Patients that have suffered through a stroke, Patients with Autism, Patients with Parkinson's, and Elderly audiences.

After thorough investigation of user needs and how these needs would translate into our project design, we decided to select one type of audience to become the focus group for our prototype. This would allow us to create a device specifically targeted at that audience and directly address their needs as opposed to the attempt of catering to a larger audience, but ultimately becoming less effective in fully meeting the needs of a larger audience. Our device however, is beneficial to any end user whose goal is to increase or maintain mobility and strength in the upper limbs, with the need for exercising cognitive thinking and hand eye coordination in a either a one-to-one or collaborative approach to rehabilitation.

The following alternative solutions were considered and evaluated alongside our current Music to Movement design to undergo further development:

1) *Full Body Theremin:* A Theremin is an electronic musical instrument that is controlled without physical contact. We proposed for the development of a Theremin which uses all parts of the body's extremities to create music. One side of the body would potentially control volume, while the other controls pitch. This would help patients develop motor proficiency, visual-integrative abilities and sensory function.
2) *Telescoping Arm:* We proposed to create a telescoping mechanical arm which would house several pads that gives light and audio feedback when interacted with. The purpose of the telescoping arm is to provide a stable mechanical base that is height an orientation adjustable which allows for reach in different planes for physical rehabilitation.
3) *Digitizer on Tracks:* We proposed to create a M2M device composed of metal tracks which give fixed orientation to digitizer music pads that allow translation in horizontal and vertical directions. The digitizers can work individually, sending light and audio feedback when interacted with and can be removed from the tracks if necessary. This is similar to the solution described above, but the range of motions is constrained by the track design in exchange for higher durability.

During our evaluation period, we discussed the above solutions and the solution that would become our final design with music and occupational therapists in and around Vancouver. Our final approach and design was chosen to move forward into development because it allowed for the greatest range of motions, and became the most flexible to develop in design. It will allow music therapists and physical therapists to use the device in any configuration possible, expanding the library of motions that can be used for physical rehabilitation and allows for multiple patients in a collaborative setting.

Solution

Music to Movement is a series of interconnected electronic sensory devices intended to help patients develop and improve fine motor skills and muscular control through the use of rhythmic music. This is done by targeting key motions used in physical rehabilitation in conjunction with devices that replicate activities of daily living. Listening to music has also been linked to improve cognition, including attention span, memory, organization, and problem solving skills, as well as furthering speech and communication recovery when users are encouraged to sing along. M2M has effectively integrated audio, visual and tactile feedback into the devices. This not only provides encouragement to users, but also helps them and

therapists understand their level of achievement during exercises. To ensure both an engaging and motivational tool, a user interface was also developed to provide game modes for patients to play along with. This is a major improvement over previous rehabilitation tools that patients lose interest and motivation in.

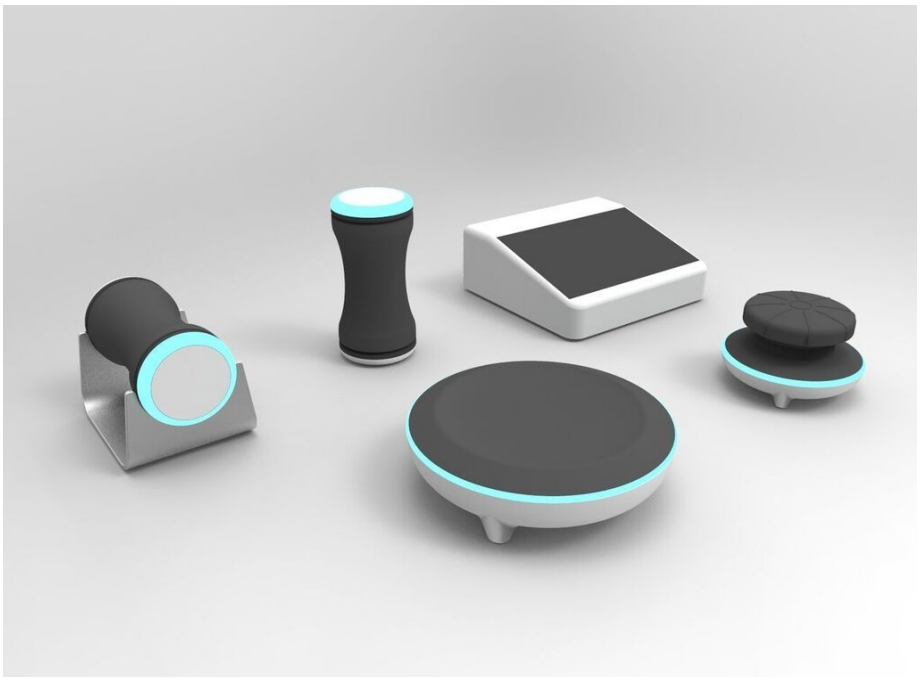

Figure 1. Rendering of a Music to Movement Device. The device features four peripheral devices: a tap device, a spin device, and a squeeze device positioned horizontally and vertically.

M2M does not only provide a new and engaging way to experience rehabilitation, but is also able to monitor patient progress to quantify developments made in strength and movement according to exercise routines. This data is acquired over multiple sessions and provided through the user interface to therapists in order to help them develop better rehabilitation routines and learn what is working for specific patients. By storing data from each patient session in a SQL database on the therapist's secure hard drive, through the M2M program, therapists and their patients can view and compare the progress made in force exerted, time response, and frequency of movement over the course of the patient's rehabilitation, which is not only limited to music and physical therapy sessions, but all other efforts made in their physical recovery. This is a huge development in the world of rehabilitation, as quantified data is hard to acquire for any physical rehabilitation program.

M2M consists of three peripheral devices, all connected a central hub. This hub not only simulates the different available game modes, but also controls the difficulty of each device. It

is the central control and data storage centre for all peripheral devices and also contains the speakers for the systems music.

The “Tap” is the first peripheral device focused on achieving accuracy and strength in hand movement. It is intended to target both forearm and wrist movement, mainly focusing on increasing strength. Additionally, the Tap was created to replicate the shape of a drum to encourage the idea of music in rehabilitation. The “Squeeze”, the second peripheral device, focuses on adapting patients to motions that involve grabbing and holding objects. This is done using a cylindrical, yet ergonomic shape that facilitates strength building. The Squeeze also encourages developing finger grip strength as this is a crucial aspect in many activities of daily living. An accelerometer in the Squeeze device allows readings to show in both vertical or horizontal orientations, which exercises different muscles. Both of these devices use custom made piezoelectric sensors using velostat, to measure pressure, which leads to providing vibrational and visual feedback to the user. An LED provides different colours of visual feedback depending on the intensity of pressure that the user applies. The last peripheral device is the “Spin”, focused on reacquainting patients with torsional motions. This primarily targets hand and forearm muscles that are less frequently used. In addition to building strength, the Spin allows patients to focus on achieving a wider range of motion while developing better hand control. The Spin utilizes a spring system in conjunction with a hall effects sensor to measure torque and provide visual feedback from an LED.

Outcome, Testing and Feedback

M2M is currently in its third prototype iteration. This is in response to feedback from music therapists, patients who have experienced strokes, as well as industrial designers that we are collaborating with in the design of the M2M. The current iteration is focused on achieving consistent sensor readings while developing more ergonomic and patient friendly designs. This includes having a robust device that patients with little motor control can handle roughly.

The shape of the periphery devices have undergone a significant change from previous prototypes to provide improved ergonomics. Improvements include slight modifications in the shape of each peripheral device to optimize the efficacy of the devices. This ensures that the maximum number of muscles will be used with each peripheral device.

Currently M2M is preparing for clinical trials of the device with local rehabilitation centers (GF Strong and City Center Care Society) in the Vancouver Lower Mainland area. This will provide extremely valuable information in regards to the efficacy of each peripheral device and end user feedback. Additionally, it will allow therapist to collect and analyze data collected from M2M to quantitatively monitor patient progress.

Prior to commencing clinical trials, it is pertinent to the success of M2M that an effective and engaging user interface be established. This will be done by ensuring game modes are interactive, fun and motivational. Testing of the user interface will take place with patients who are currently undergoing physical rehabilitation while working in conjunction with music therapists who may facilitate any rehabilitation exercises.

Cost for Production and Expected Pricing

To determine the expected pricing of our device, we looked at the cost to produce our product and also performed a competitor analysis on major stroke rehabilitation devices in North America. We found that at our current projections, it would cost around $50 per peripheral device and $200 for a hub. Our major cost is in the hub control components, which are the microcontroller, memory card shield, and music shield. We believe in future development, we can look contract manufacturers that can integrate the functionality of those components into the PCB to bring down production costs of the hub to approximately $50-100 for medium-high volume production. Other methods of bringing down cost would be to purchase in higher volumes than those used in prototyping.

A cost that is not addressed are silicone interfaces that primarily the patients will be handling during the sessions. This allows the device to be easily sanitized between each user. The cost of creating silicone parts require molds and injection molding for higher volumes. This presents a high capital cost, but low cost to manufacture per part. We are expecting an upfront cost of $2000-5000 tooling cost for each peripheral device, and $20 dollar per M2M unit. This cost is expected to be refined as we contact contract manufacturers for quotes on setting up our production processes.

From the above analysis, we believe the cost to produce a M2M device will be approximately $250-$300 for a basic M2M kit, not including the tooling cost. By looking at competitor devices, such as the Flint Rehab Music Glove, Saeblo Glove, and Rejoyce Rehabtronics, we've found that the most comparable Music Glove will cost a clinician $1178-3300 USD and $459-989 USD for a patient. We've also asked our target consumers, our partnered music therapists what they would expect the M2M device would cost if it met all their requirements. By taking these factors into account, we believe a competitive cost for an M2M kit would be $1000 CAD for clinicians, which gives them the ability to measure physical rehabilitation progress, have a full range of motions, and can be set to varying difficulties as a patient's outcome improves and exercises become easier as opposed to the competitor products mentioned above.

Significance

M2M is addressing a dire need for innovation in the field of stroke rehabilitation. Currently, patients who have suffered from a stroke are not receiving adequate physical rehabilitation using the available tools on the market. These tools are either very unengaging or can be extremely expensive for therapists to purchase, resulting in patients giving up on their rehabilitation as a whole. M2M fills a gap in the market by providing a fun, engaging and motivational tool for patients who have suffered a stroke. This allows individuals to return to a normal lifestyle more quickly, having an effect on the lives of both the individual and their families. A device that actively engages the patient and introduces light-hearted fun into a rather difficult situation can have immeasurable effects on the patient's attitude and mental health throughout the duration of their recovery.

M2M is unique particularly due to the focus it gives to using music in rehabilitation. Music has been proven to positively impact the cognitive functions of individuals of all ages. Integrating music into rehabilitation can have a significant impact on an individual who has experienced a brain injury, contributing to the rebuilding of sensory integration and cognitive functioning. M2M will be an affordable alternative to current expensive technologies on the market with the added benefit of combining traditional physical therapy with therapeutic music strategies. The device will allow users to gradually develop their skills while constantly monitoring their progress with the ability to increase difficulty at any time. The simplicity of the device also allows patients to perform exercises without the constant supervision or aid of a therapist and can be used as a way to complement the treatment they would normally receive at scheduled therapy sessions. For these reasons, M2M effectively fills a gap in the market for an affordable yet effective physical rehabilitation device.

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Format

- 6 pages maximum (plus acknowledgements/references), 8.5x11in, in PDF Format

- Teams must also submit a text-only version in Microsoft Word; this will be used for publication
in the RESNA Conference Proceedings for finalist Teams.
- Font size 12 minimum, minimum 1in margins

- Photos
    - At minimum, a product photo (final or prototype) is required ○ Additional photos may be included if desired
    - All photos should measure at least 2inx2in

Format should showcase work completed, while maintaining a professional approach and appeal. Teams may exercise creativity in presenting their work, as long as the formatting guidelines are met.