Music Therapy Proposal

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1 Introduction

Parkinson’s Disease, Multiple Sclerosis, and Huntington’s Disease are a few of the debilitating conditions that have a devastating effect on motor function. These diseases can only be treated, not cured. By developing effective treatment plans, the progression of damage can be better managed and increase quality of life. Looking at small-scale solutions, simple and accessible treatments have yielded promising results that act as a supplement to major and invasive surgeries.

Our idea is to create a wearable device that can track the gait of a Parkinson's patient to assess progression of the disease and additionally be a therapy tool to improve motor function. Gait analysis is a method in diagnostics for motor disorders such as Parkinson’s or Huntington's Disease and can track the degradation or improvement of a patient’s motor function. Music-based interventions have shown great benefits in the treatment of motor impairment that translates to cognitive, speech, and language rehabilitation through entrainment, the temporal locking process in which one system’s motion or signal frequency entrains the frequency of another system. In this case, the motor system locks with the rhythm of music. Rather than the established use of music therapy alone, utilize a wearable that will alter the speed/rhythm of the music played to develop a feedback system with positive reinforcement.

2 Problem Description

A number of neurological and degenerative diseases cause motor function impairment that can greatly decrease the quality of life, independence, and health and safety of patients. This degeneration can be rapid, and in cases where the source of motor impairment is incurable, the recovery process can be lengthy, difficult, and yield minor improvements if any. Since the causes are so vast, there are many medications, therapies, and rehabilitation treatments that vary in effectiveness, carry risks, and have high costs or low accessibility. The goal is to find a treatment method that is non-invasive, low-risk, low-cost, and accessible as well as proven by extensive research and widely applicable to the range of people affected by motor dysfunction.

Music therapy is growing in popularity and recognition as a treatment for motor dysfunction. This approach will be applicable for rehabilitation after stroke, Parkinson's Disease (PD), Multiple Sclerosis (MS), Epilepsy, traumatic brain injury, and more. Specifically, in PD, the timing and size of repetitive sequences of internally generated automatic movements are particularly affected. The most evident consequence of this deficit is the alteration of gait patterns, including loss of rhythm, shorter steps, slower gait, and trunk instability. Music-based interventions can positively affect functions such as motor performance, speech, or cognition in these patient groups. The psychological effects and neurobiological mechanisms underlying the effects of music interventions are likely to share common neural systems for reward, arousal, affect regulation, learning, and activity-driven plasticity.

Entrainment is at the root of the principles of music therapy. It is defined as a temporal locking process in which one system's motion or signal frequency matches or

persuades the frequency of another system to adjust to its own. The stronger signal entrains the weaker signal with one adjusting the other, or if the two are equal, they both adjust to meet in the middle. In our case, the rhythmic signal causes the temporal-motor system to adjust and match its frequency. Studies using fMRI and magnetoencephalography observe the brain's response to rhythmic input and locate where in the brain activity is occurring. It was found that even when the conscious mind did not recognize a rhythm change, the brain activity reflected recognition of the shift, and motor functions such as tapping were affected. Therefore, the auditory system is clearly interlocked to the motor system by multiple pathways and sensitivity to changes in input. In summary, auditory rhythm acts as a forcing function to optimize motor control across all facets and the rhythm input influences movement timing as well as modulates muscle group activation patterns and the control of spatial movement.

With the extensive research compiled to support the success of these therapies and the exploration of neural pathways in the brain, the plan is to take an organized and technical approach to how rhythmic auditory stimulation in conjunction with structured movement and timed tasks can improve motor functions such as gait velocity, cadence, stride time symmetry, stride length, weight-bearing time, stride variability, and balanced muscular activation pattern.

3 Proposed Solution

Our proposed solution is a wearable device that can be worn comfortably, tracks the patient's gait, performs software processing of the gait metrics to determine corrective response by the device, uses this information to alter the tempo of the

selected music, and physically transmits this music (wired) to the patient via an audio device.

Our device will be designed to be conveniently wearable. This modular “device” (including all hardware components) will attach to the patient at the hip, via a belt clip or similar hardware. It will be capable of holding and supporting the weight of the gait tracker, associated electronics including the battery, and the output of our chosen wired audio device. This will all need to be contained in a physical “box” to hold our finished modular product.

One of the main functions of our product will be the accelerometer, used to track the patient’s gait. A motion sensor (accelerometer) will be configured to track hip displacement across space, indicating the frequency, length, and time of the patient’s steps. These are all key metrics that will determine how the patient’s motor skills are functioning, and what music therapy is most appropriate in real-time. This will be done with a microcontroller, wired with associated electronic passives and a rechargeable battery. The collected information will be sent via SPI or I2C to the software processing stage.

With the physical gait metrics collected, code will be written to analyze the information and compare it to pre-set standards. Based on variation from pre-set (adjustable) gait frequencies, lengths, etc. various options of music can be selected. This processing will include physical metrics from current research on music therapy’s effect on Parkinson’s and Huntington’s patients, and use this research to determine the pre-set standards and most applicable musical responses.

The musical recommendations from the software processing function will then be used to modify the music being fed to the audio device. This will be done to pre-loaded music with known characteristics. The music will physically be transmitted to the patient via wired headphones, with an audio jack feeding from the wearable device itself. This way, one will also be able to use a speaker if desired.

4 Demonstrated Features

1. Motion sensor (wearable hardware)
    a. The accuracy of the accelerometer will be demonstrated physically in real-time.
    b. Various walking tempos, and the transmitted results, will be shown on OLED display.
2. Gait tracking digital processing (tempo-tracking software)
    a. The frequency of the gait will be shown to be properly calculated on an OLED display.
3. Music tempo variation (dependent on gait)
    a. Audience members will be able to use the device, and experience firsthand.
4. Music Selection based on personal preference and desired pace (user interface via pushbutton)
5. Modularity and Useability
    a. The finished product is constructed well enough physically to stay attached to the patient during tempo variations and sudden movements.
    b. The device will be visibly attractive and modular.
    c. Rechargeable battery (with status indicated on OLED).

5 Available Technologies

To solve your problem, there may be particular technologies or parts that you will need to apply. For example, if you are going to have a wireless interface, you will need to find wireless transmitters and receivers to provide this function, or design those items yourself.

This section should include specific technologies that you think might work to provide the functions required in your project. Note that you might not end up using the particular technology listed in this document because over the course of the design you have discovered a better or more appropriate technology.

Remember that you are dealing with limited budgets, so available must include affordable. Each team will have about $500 to spend on the project. (Note that making a circuit board will cost about $50.)

This section should have sufficient information to convince me you will be able to do what you are proposing. ***Remember that parts availability is still a very big issue.***

Part Type	Part No. & Link	Description	Cost
Motion Sensor	ICM-42670-P	3-axis accelerometer with I2C/SPI Interface	$4.80
Microcontroller	ESP32-S3-WROOM-1 Module	Microcontroller	$3.20
Audio Codec Chip	ES8311	Contains DAC, pre-amplifer, headphone driver, digital sound effects, analog mixing, and gain functions	$0.47
Audio Amplifier	NS4150	Amplify audio signal for headphone/speaker output	$1.17
Audio Jack	TRS Audio Jack	Used to connect headphone/speaker	$0.75
USB-to-UART Bridge Chip	CP2102N	Connect microcontroller to PC to program/debug	$4.44
USB-to-UART port	UJ31-CH-G2-SMT-TR	Self-explanatory	$2.50
Buttons	In stock	Buttons for user interface	<$1.00
Micro SD Card	SanDisk 1GB MicroSD	Memory for storing audio files	$15.89
Micro SD Socket	Micro SD Socket	Insert Micro SD	$1.95
OLED Screen	1.3" 128x64 graphic display	Used for interfacing with user and selecting settings	$19.95

Total Cost: $56.12

6 Engineering Content

Major Functional Blocks

1. PCB Design: include power, accelerometer, audio output, LCD
2. Determine appropriate amount of memory allocation and facilitate communication with the existing chip
3. Accelerometer I2C/SPI communication
4. Gait-sensing algorithm testing and optimization
5. Hard drive/microcontroller communication for audio
6. Real time audio tempo processing
7. Output the modified audio data to headphones or speaker

7 Conclusions

Music therapy is a significant tool growing in popularity as a treatment for motor dysfunction. Our design utilizes the recognized principles of music therapy and expands on its common application. The goal is to realize a new research concept of music therapy with tempo-matching to gait speed; this idea utilizes the base benefits of music therapy while adding positive reinforcement, feedback, and therapy personalization. This approach will be applicable for rehabilitation after stroke, Parkinson's Disease, Multiple Sclerosis, Epilepsy, traumatic brain injury, and more.