Lord of the Butterflies: An Ambulatory Enablement Game

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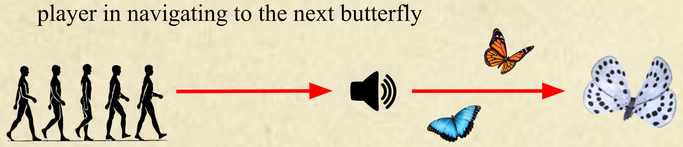
Introduction

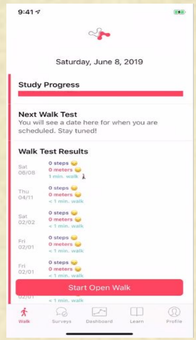
- *Lord of the Butterflies* is an augmented reality game where a player is out on quest to save the spotted-white butterflies from the toxic environment
- The game uses audio reinforcement cues and visual aids to assist the player in navigating to the next butterfly



- *In this post-apocalyptic world, many species of animals have died from breathing toxins in the air.*
- *The snowy-white butterflies have just escaped their chamber, and it is your mission to rescue as many as possible in 3 minutes.*
- *As Lord of the Butterflies, their fate is in your hands.*

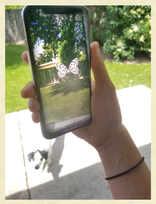
Motivation

- This game is targeted to improve the motor abilities of people who have difficulty walking (e.g. people suffering from Peripheral Artery Disease (PAD), Congestive Heart Failure (CHF), and recovery after stroke
- This goal-based motor training game modifies cortical circuitry to improve motor function by re-aligning biomechanical and neuromotor control
- Prior research has found strong correlation between hyperactivation of motor cortex and walking improvement
- Cognitive engagement of the game can help consolidation of learned behavior to strengthen/modify existing motor circuits



Mobile Device User Interface

Motor Learning and Healthy Gait Recovery



Subject Playing the Game

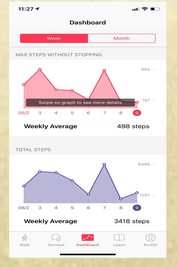
Data Analysis

- Using iPhone sensor data (accelerometer, gyro, cadence, etc.) we are measuring workout power
- Power is a measure of walking intensity during the game that will modulate the sound of wind

For any time period t,

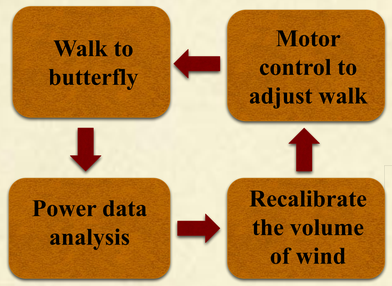
$$power = \mu \times a$$

μ = average cadence
a = average acceleration of the x-vector



Gameplay Environment

- Player interacts with augmented reality via their mobile device and wears the Bose glasses for auditory information
- Player hears a metronome (butterfly flaps) and should synchronize their walking gait on their path to capture a butterfly
- Player will receive auditory feedback through the sound of wind that modulates according to their walking power
- Player is rewarded for walking longer sustained periods without decreasing in power
- Foreground butterflies will change color if the user is performing at a low power for too long

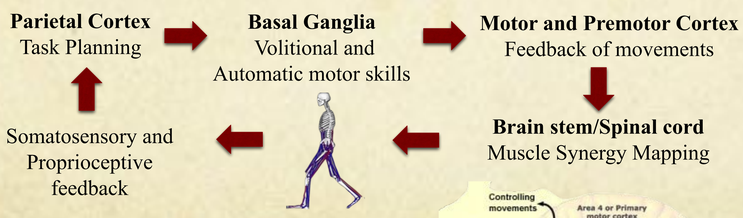


Gameplay: Loop structure that provides auditory and visual cues so the player can modify their actions

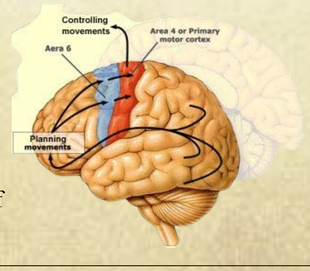
User Interface: the white butterfly is in the background and the changing color butterflies are in the foreground

Neuroplasticity

- Walking is a complex coordinated activity mediated by networks involving cortical, subcortical, and spinal regions
- Parameters for neurorehabilitation: intensity, repetition, and specificity
- The games repeated motor actions leads to plastic reorganizational changes in primary motor cortex
- Subjects who are given success-based reinforcement signals have increase use-dependent plasticity in motor cortex



- This game forces the player to adjust their movements to capture a butterfly
- Players learn which actions lead to success, and try to recreate those movements from memory
- The game aims to drive neuroplasticity of circuits involved in automaticity



Discussion

Design Choices

- Engaging immersive environment to promote consolidation of learned motor movements
- Task-oriented learning to encourage the player to walk with a healthy gait and maintain high power
- Sound of wind reinforces healthy actions that will be repeated for learning
- Color of the foreground butterflies adjust based on performance over time

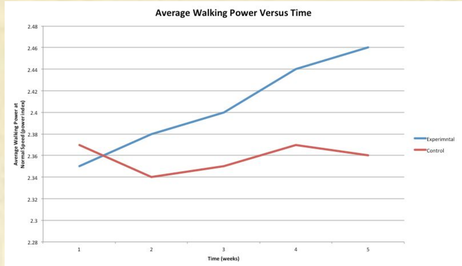
Testing (Pre/Post-Test)

- Experimental group plays the game over several weeks (training)
- Control group has walking trials with no game intervention
- *Post-Test* game environment: no reinforcement cues (auditory or visual)
- Performance is measured by average power exerted over time

Hypotheses

1. Subjects will increase their average walking power through a task-specific rehabilitative game, i.e. experimental group performs better in post-test
2. Subjects will show increase neural activation in premotor cortex (planned motor execution) and primary motor cortex (voluntary motor control)

This is a graph of *expected data* comparing game intervention subjects to a control group



Future Directions

- Integrate a walking path to butterfly that records data for balance
- Metronome adjusts to player performance
- Track neural activity with EEG cap
- Novel use of sound to indicate health data (flight climbed, distance, etc.)

Acknowledgements

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