myWaldo: wearable technology for quantifying and modifying generalized muscle weakness

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Abstract
For many people with neuromuscular weakness due to Myasthenia Gravis, planning activities around potential and/or actual muscle weakness is time-consuming and emotionally draining. Knowing how the muscles behave with particular activities can inform behavioral modifications that will enhance social and emotional well-being. Using electromyography (EMG) sensors and microcontrollers, myWaldo quantifies and records illness and fitness in relation to neuromuscular diseases that cause generalized weakness in voluntary muscles. By quantifying muscle weakness patterns during daily activities and exercise, an individual can make modifications that will enable them to save energy and muscle strength for when they need it.

Author Keywords
design; microcontroller; muscle fiber; electromyography; muscles; fitness; myasthenia gravis; neuromuscular; behavioral change; quantified self

ACM Classification Keywords
Design; experimentation; measurement; performance; standardization

Introduction

Myasthenia Gravis is a chronic autoimmune neuromuscular disorder causing fluctuating weakness of the voluntary muscle groups [1]. Muscles become weak during activity and improve after rest. The disease "is caused by a defect in the transmission of nerve impulses to muscles. It occurs when normal communication between the nerve and muscle is interrupted at the neuromuscular junction…[by] antibodies [that] block, alter, or destroy…receptors…at the neuromuscular junction, which prevents the muscle contraction from occurring" [2].

People with Myasthenia Gravis face constant changes in their physical capabilities throughout the day. Repetitive muscle use weakens muscles, causing physical exhaustion, difficulty moving limbs, chewing, swallowing, talking, walking, and even breathing causing an uneven impact on the ability to work, socialize, and to plan for the future. These changes fluctuate hourly, daily, and over time, therefore being able to monitor these changes will allow people with weakness in their voluntary muscles to make slight adjustments to their activities in real-time so they can conserve energy, not 'over-do' their exercise, and 'save' it for later in the day.

Besides medication, "lifestyle changes" are generally part of the adaptations to living with the disease. They mainly include adjustments to eating (when muscles are strong, eating soft foods, and eating small amounts, slowly), installing safety equipment (grab bars), and most importantly, to plan carefully [3].

> **"Plan.** If you have chores, shopping or errands to do, plan the activity to coincide with the time at which you have the most energy. Also, try to reduce extra walking in your house when working on projects, as it may reduce your energy" [4].

The exhaustion and muscle weakness vary with daily activities, making it difficult to complete simple tasks or conserve enough energy and strength to complete an entire day's worth of activities. The purpose of myWaldo is to collect individual muscle data over time with multiple activities in order to enable the modification of behaviors both with immediately as well as with long-term patterning.

Research Questions

Using currently available open-source electromyography (EMG) sensors and microcontrollers, can we quantify muscle fatigue in people with neuromuscular diseases? Will collecting EMG signals during daily activity be useful on an individual level for behavior modification to enable better (more pinpointed) use? Can the data collected be used as a way to slowly increase muscle use and therefore tone, based on individual's own assessment of their weakness?

By analyzing individual patterns and levels, the idea is that over time, a person can compare their current levels with previously collected data to understand and plan their immediate activities- such as whether to exercise or not, or take the elevator instead of the stairs. Additionally, if at some point in the future the personal data is aggregated to a central database, could it be useful to neuromuscular researchers?

Conceptual Framing

myWaldo will be a wearable device that connects with software for data storage and analysis, and is based upon a blend of currently available wearable technologies and ongoing medical research using electromyography in rehabilitation.

In medical research and rehabilitation, the EMG is used as a diagnostic tool for neuromuscular disorders [5]. It is integrated into physical therapy [6] and rehabilitation after stroke, for reduction in spasticity after spinal cord injury [7], and even for increasing hemoglobin levels in diabetes type II patients [8]. This research uses high-cost, medical grade electromyography, whereas in the commercial health and fitness movement, they use simplified sensors to monitor and streamline one's own physical exercise training effectiveness [9] [10] [11] [12].

myWaldo is wearable technology inspired by Robert Heinlein's story *Waldo*, wherein the main character, born with congenital Myasthenia Gravis, creates the "Waldo F. Jones' Synchronous Reduplicating Pantograph" [13], essentially pairs of embedded gloves which enable him to control larger gloves with more energy and force to accomplish tasks beyond the ability of his own muscles. As a classic case of a person with an outsider perspective [14] [15], Waldo creates 'technology' that is useful for the 'center' as much as for himself. So to with myWaldo; where I use my own generalized muscle weakness as case-study for the design and implementation of myWaldo hardware and software.

Methods

The first stage of testing incorporates the open-source sensors that are available now to see if and how these might be used. Most readily available low-cost circuits and sensors available today use smoothed sin waves instead of raw data, making them acceptable for tracking healthy individuals during regular training intervals, such as running or bicycling [16]. This first stage of testing will answer whether these sensors are sensitive enough to collect the muscle data needed for neuromuscular disease weakness.

I am currently using Advancer Technologies' EMG circuit as a way of collecting initial data on myself. I have a neuromuscular disorder that causes generalized muscle weakness of my voluntary muscles during repetitive activities, such as running, climbing stairs, writing, chewing, swallowing, and breathing.

The second stage is to build a better, inexpensive sensor-circuit-software combination so as to collect raw EMG data instead of smoothed sin waves [17] [18].

Additionally, ongoing design research explores how the hardware (concerns include wearability, portability, wireless transmission, battery life), and software design (seamless interface, simple to use, visual, positive) interface with an individual's body.

Finally, the structure of the data collected must be carefully considered, so as to be useful by itself and also within the larger context of other information that the user can input into the database.

Implications / Conclusions

Currently available wearable technologies using EMG are aimed at healthy, active users who are trying to quantify their own activities for optimal fitness. By creating low-cost options for people with Myasthenia Gravis, individuals can first have more control over their energy expenditure and muscle use, for daily activity and energy conservation, second can use long-term data to help them become stronger over time, and third, can monitor progression/regression of their symptoms over time.

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