EMG Controlled Lego Mindstorms (Brain Machine Interfaces)

Date: 03/11/13

Authors: Brad Patterson, Shoai Hattori

Objectives:

- Explore how the brain and nervous system produce movement via electrically-induced muscle contraction
- Demonstrate how these electrical signals can be detected for medical uses via Electromyograms (EMG)
- Discuss brain-machine interfaces and the benefits of the technology - how they can be used to restore lost functionalities like movement and sensation (e.g. using EMG signals to control prosthetic limbs)

Materials and Supplies Needed:

Item	Quantity	Notes (Vendor, price, purpose, etc.)
Lego Mindstorms	2-3	Lego.com $279.99/ea - requires assembly
Custom made EMG amplifier/rectifier with electrodes	2-3	One for each lego mindstorm kit. Requires custom building. Estimated raw material cost ~$180
Masking Tape	1-2	~$5/roll For making a "track" on the floor for the participants to navigate with the EMG-mindstorm robot
Alcohol Swabs	1 box (optional)	$3/box of 100 at Walgreens For cleaning the skin before attaching EMG electrodes - better conductance
AA Batteries	1 pack of 24	Batters for lego mindstorms (requires 6 AA batteries per robot) ~$20 for pack of 24 from various vendors
1 Laptop with Lego Mindstorm software and the custom written program	1	To re/load custom-written program onto robots

Background Information / Activity Explanation:

The nervous system works by sending electric signals throughout your body (similar to the wiring in your house or in your computer). Using these electric signals, you can see, hear, taste, touch, smell, think, feel, and move. Most simply put, movement is produced by the brain (specifically, the motor cortex being one main area of movement production) sending electric signals down the spinal cord to the muscles. Once the electric signals reach the muscles, the muscles contract, allowing body movement.

During the process of muscle contraction, a lot of electricity is also produced by the muscle (not only do muscles receive but it produce electricity). The electricity produced can be detected and measured using a device called an electromyograph with surface electrodes. The electric signals that are detected by the electromyograph are called electromyograms (EMGs). Based on the strength or intensity of the movement, different levels of electricity are produced and detected. Stronger movements produce larger

electrical signals, while weak movements produce small signals. EMGs are commonly used in research for studying strength of movements, biomechanics, and the nervous system. EMGs are also used to diagnose different neuromuscular disorders and diseases (for more info: http://en.wikipedia.org/wiki/Electromyography).

More recently, EMGs have been used to develop **brain machine interfaces** which is a direct communication pathway between brain signals and an external device. They are aimed at assisting, augmenting, or repairing human cognitive or sensory-motor function. For example, a lab at Northwestern University has developed technology that is able to detect EMG signals and use that to control a prosthetic, robotic arm (Targeted Reinnervation), benefitting amputees that have lost an arm.
For more info about EMG-based brain machine interfaces and targetted reinnervation:
http://www.youtube.com/watch?v=We9O1CJusAU
http://www.youtube.com/watch?v=T6R5bm6qx2E;
http://www.ric.org/conditions/po/services/bionic/).

In this activity, we will detect EMG signals from participants' muscles while they flex their arms and use the EMG signals to control the wheels of a Lego Mindstorm robot (i.e., flex right arm, right wheel moves. Flex left arm, left wheel moves).

Procedures:

Pre-Activity steps:

1) Using masking tape, create a track on the ground with a configuration containing various left/right turns.
2) Assemble lego mindstorm robot - basic configuration in the Lego instruction manual is sufficient.
3) Plug one end of the gray ribbon cables into ports 1 & 2 on the Lego Mindstorm Brick.
4) Insert the other ends of the gray ribbon cables into the two ports on the amplifier.
5) Connect EMG electrode leads to amplifier.
6) Turn on the Lego Mindstorm Brick by pressing the orange button.
7) Navigate to “My Files > Software Files > SelfCalEMGCar” [orange button=”enter”, black button=”back”] – the software should already be downloaded.

Steps during activity:

8) EMG electrodes are equipped with a Velcro armband. Place armband end on the subject’s biceps (ventromedially). Place ground finger lead on the subject’s thumb.
9) Repeat for other set of leads on the other arm. DO NOT CLEAN LEADS WITH ALCOHOL. Optional: if subject’s arm is oily, clean skin with alcohol swabs. Let alcohol evaporate before attaching EMG electrode leads.
10) Turn gain on amplifier to max.
11) Place robot upside down so that the wheels are pointed up and press “run” on the Brick (orange button).
12) Test to make sure the robot is calibrated and responds appropriately to the EMG signals - Adjust the gain down as needed such that the wheels barely respond (if at all) when the arm/muscle is relaxed, but does respond well (moves well) when muscles are flexed.
13) Once calibrated, place Lego Mindstorm robot on the ground with the wheels down.
14) Allow subject to control the robot with flexion/relaxation of their muscles – Have them try to follow a track on the ground that is laid out with masking tape as fast as they can.

To switch between subjects, press the black, “back” button on the Brick to stop the program from running. Remove EMG electrodes by undoing the Velcro armbands. Repeat steps 8-14 above.

Additional Information (advice, spiel, links, figures, etc.)

- Recommended that participants perform this activity in the seated position to prevent tangling, tension, and damage to the leads and cables. Place the EMG amplifier/rectifier circuit on a table and secure it using tape. Place a chair immediately next to the table so that there is enough slack in the EMG electrode wires.
- After calibrating, the volunteer can make sure the ribbon cables between the Lego Mindstorm robot and the EMG amplifier do not tangle.
- The robot can only move forward so if the robot veers off course, have volunteers move it back on track.
- If there is a long queue for this activity, you can have two people go at a time on one robot – one person controls one set of wheels and the other person controls the other set of wheels. This configuration requires team work to successfully navigate the course.

If interested in building the custom EMG amplifier/rectifier and/or for a complete list of supplies needed, contact Shoai Hattori at shattori@u.northwestern.edu.