INTRODUCTION
Currently in the United States there are around two million people suffering from limb loss and 250-300,000 persons living with spinal cords injuries [1,2]. While these handicaps do not prevent living independent lives, their lives could be greatly improved with replacement limbs, or prosthetics. People relying on others to assist them could no longer need others to rely on and live independently. Brain computer interfaces (BCIs) pick up electrical signals from the brain and translate them in computer commands. Specifically, signals from the motor cortex used to direct limb movement can be recorded and translated to direct prosthetic limb movement. This can help those either without limbs or independent limb control. When a subject uses a BCI, the user requires real time feedback to properly perform tasks [3]. Examples of this are watching a cursor or virtual arm move onscreen or a robotic arm performing a task in front of them. Recent experiments have shown that subjects respond better to physical feedback such as task performed by a robotic arm over onscreen feedback [4].

The BCI programed used in this experiment is Craniux8. Craniux8 receives electrical signals and translates them into motion commands via its internally built neural decoder. In place of a human subject for this experiment, an Electrocoretigraph (ECoG) simulator was used as the focus was on the motion commands not processing of neural signals. The ECoG simulator produces signals alike to an ECoG grid on a human scalp, but as it is controlled by a three dimensional joystick it produces constant signals for the same direction. In this fashion, certain channels are more active when moving in one direction akin to certain neural clusters firing when directing arm movement in a specific direction. Recording which channels are more active for certain directions allows the construction of a neural decoder. This decoder can then immediately interpret new neural data, in this case from the ECoG simulator, and produce movement without computer assistance.

The robotic arm used with Craniux8 is a DEKA prosthetic arm. The DEKA arm is a modular prosthetic limb (MPL), a humanlike prosthetic in strength, dexterity, and appearance. Using a prosthetic like an MPL designed to replace a lost arm is ideal as the ultimate goal of BCI research is to have a replacement limb that is controlled by the subject’s own BCI outside of the lab.

Until recently, no control program for the DEKA arm existed within Craniux8. Instead, the primary application was a virtual MPL that was viewed onscreen. A merging of these systems will allow a subject to control the DEKA arm through Craniux8.

OBJECTIVE
The objective of this project is confirm that the DEKA controlling module written for Craniux8 performs to the standards of the existing virtual MPL (VMPL) control module. Both arms can be compared through their electrical signal intensities for identical movement commands.

EXPECTED OUTCOMES
The expected outcomes of testing each arm are that all neural channels from the ECoG simulator should fire at similar frequencies when performing the same movements. Additionally, trials with each arm should produce a usable neural decoder.

METHODS
To interface Craniux8 with the DEKA arm, modifications to both existing programs had to be created. Modules were added to Craniux8 in both MATLAB and LabView to send and receive data packets from the DEKA arm and a control program for the physical targets for the arm. The standalone DEKA control program was then rewritten to receive commands from Craniux8 and send out real time position and other data back to Craniux8.

Once the entire system was functional, time based reach trials were performed with each arm. Eight targets in three dimensional space would be repeatedly presented for the arm to reach for. Reaching the target within ten seconds would be considered a successful trial. Three rounds of these target reach trials were done for both the VMPL and the DEKA arm. The first trial would be done with the arm under 100% computer control as the ECoG simulator output data as if it was controlling the arm. This is akin to a subject being asked to think about moving the arm as it moves without having control over the arm. This data of “thinking” was recorded and used to build an initial neural decoder. The second round of trials was performed with this neural decoder in place and the arm under 50% brain (ECoG) control. The computer assisted the arm by having 50% of the control ensuring targets would be reached. The ECoG data from commanding the arm to move allows for a second and improved decoder to then be built as the algorithms are better able to discern the intended commands from the ECoG. A third and final set of target reach trials would be performed under 100% brain control with no computer assistance. The success level of this final round of trials determines the effectiveness neural decoder built.

RESULTS
Both the VMPL and DEKA arm had successful percentages in the final time-based target reach trials, 78% and 87%
respectfully. Each percentage is high enough to indicate a useful neural decoder was built.

Focusing on one target, one forward and down from the starting center point, the VMPL had channels 18, 22, 23, 26, 27, and 31 as the most active (Figure 2). For the same target the DEKA arm had the same channels as most active (Figure 3). Figure 1 displays the frequency-time plots given for all the channels in both Figures 2 and 3.

![Figure 1](image1.png)

**Figure 1.** Individual time-frequency plot for single channel. Averaged over all trials for a single target, higher areas or red indicate a more active channel for a certain direction.

![Figure 2](image2.png)

**Figure 2.** VMPL results. Average time-frequency data for the VMPL when reaching for a target forward and down from the arm’s center starting point. Channels encircled in red are the most active.

![Figure 3](image3.png)

**Figure 3.** DEKA results. Average time-frequency data for the DEKA when reaching for a target forward and down from the arm’s center starting point. Channels encircled in red are the most active.

For all targets, including the results shown in the above figures, identical channels were active both the VMPL and the DEKA arm. Furthermore, these channels were the same channels that were active in the ECoG for the same movement command.

**DISCUSSION**

Useful neural decoders are needed in order to control a BCI application, in this case either MPL arm, under brain control. If a control program could not communicate well with the BCI program, a poor decoder would be created preventing successful brain control. The success rates of both arms demonstrate that both the VMPL and DEKA arm control modules produced useful decoders. Identical active channels for both VMPL and the DEKA arm when reaching for the same targets indicate that the DEKA additions to Craniux8 were both functional and performed equally to the existing virtual arm program.

Following the project, the DEKA modules and Craniux8 system are to be improved and made more time efficient. If the system is to perform coherently it must communicate data in real time and delays could hamper the entire system.

This experiment was limited by the sole use of an ECoG simulator in place of human subject. The ECoG simulator will always send out the same signals for the same movements which makes it a reliable control. A human brain, however, is much less predictable and stable with our current understanding of neural signaling. Using a human subject would demonstrate the true usefulness of the DEKA additions to Craniux8.

Looking to the future, Craniux8 is to be used with human subjects in clinical trials with the DEKA additions in place. This research hopes to better understand the motor signaling of the brain to further BCI technology.

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**REFERENCES**


