Phantom Limb Pain: A Different Approach to Treating a Common Problem

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During the summer of 2013, I worked with Dr. Pierce and the Honor’s Summer Research Program to assist in developing a new, yet different, form of a treatment for Phantom Limb Pain. Phantom Limb Pain is a painful condition that affects between 50%-80% of those with an amputation and almost all of those with a brachial plexus avulsion (Mercier et al). Phantom Limb Pain is defined as sensations in the area in which an amputation or brachial plexus avulsion has occurred (WebMD). Brachial Plexus Avulsion occurs when then nerves from the spine running through the neck and limbs is pulled out without the ability to heal (Johns Hopkins). While the sensations vary in their intensity and type, many times it is painful and often excruciating.

The cause of Phantom Limb Pain is speculated, but currently unknown with any definite knowledge. One study showed that there is no definite relationship between the time of limb loss and the time that treatment began (Mercier et al), and the same study speculates that there could be a relationship between brain plasticity, both normal and abnormal growth, and how susceptible someone is to influence. This creates great obstacles for those attempting to treat Phantom Limb Pain as well as those suffering from it. Currently, there have not been any large, double blind studies through which results can be objectively obtained and interpreted (Moseley et al). Unfortunately, there are many obstacles to doing such a study due to restrictions on the time since deafferentation, what type of injury can be accepted into the study, etc. While many case studies have
shown to be promising, they have all concluded that further research must be conducted in order to ascertain the true efficacy of their particular treatments.

While there are a large number of treatments for Phantom Limb Pain on the market today, many are turning to virtual therapy. One of the first treatments was developed by Dr. Ramachandran and is best known as Mirror Box Therapy (Ramachandran et al). The subject would take the residual limb and the remaining limb, and place both on opposite sides of a mirror inside of a box. They would then be instructed to carry out activities with both of their hands. The treatment was limited to symmetric movement due to the need to convince the subject that the missing limb was indeed moving. While the treatment worked for several patients, it did not work for everyone. In addition, the variability among the patients that did experience an effect was extremely large (Ramachandran). Another treatment by Dublin Psychoprosthetics attempted to eliminate the problem of proprioception. The developers used a glove to measure the subject’s joint angles and lengths. As they moved the limb, the opposite limb would be projected onto a TV screen performing the desired motion. Although this treatment is applicable and helped many subjects, its true efficacy is unknown. The treatment did not use an immersive virtual reality, and it utilized the incorrect side of the brain. Cole and Colleagues developed yet another virtual reality treatment. A device was attached to the residual portion of the limb, and it was projected on a screen as performing the desired motion. While this utilized the correct side of the brain and did help some subjects, the idea must still have further research pursued in order to gain a better understanding of the efficacy of the treatment. The final experiment, done by Murray and Colleagues, appears to be a blend of these three previous treatments with its
own unique aspect. Murray and Colleagues developed a fully immersive virtual reality environment in which a person could see the movements of their hand as determined and calculated by the joints and brain signals of the remaining limb. The issue with this treatment is that, again, there are no true defining features and it develops a projection of the missing limb based upon data obtained from the opposite side of the brain (Murray et all).

The ultimate goal of this project is to develop a treatment of Phantom Limb Pain that utilizes both the correct side of the brain while not limiting the body to symmetric movement. A myoelectric device will be attached to the residual limb tissue, and the data taken from the device will be used to run a computer function. That function will determine the current position of the limb and then interpret the myoelectric data to determine the next position of the limb. That program will then make the calculations necessary to move the limb from the current position to the final position while not doing so instantaneously but rather in real time so that the movement looks authentic. The movement will be displayed through a three dimensional projector which will be placed to project onto a table with reflective paint. Thus, the hand will look real and authentic. Once the project is completed, a subject will wear the myoelectric device and play a game with a set of objects on the table.

My work has been concentrated on developing the computer program. With Dr. Pierce’s assistance, I have written a generalized computer function in Matlab that takes data from three files describing a hand: the beginning position, the end position, and the translational components of each link. The program then computes then calculates the transformation matrices for each point along the hand and forms a four dimensional array
of data. These transforms and their translational components are then input into a sub-
function that calculates the universal coordinates of each point, and then these
coordinates are displayed. The program will then calculate the necessary step size for
each joint to get from its beginning position to its final position. A loop is then run that
continuously adds a respective step size to that particular rotational value. The process of
calculating the transformation matrices, calculating the universal coordinate systems, and
displaying these new coordinates is then repeated. Finally, the new system is stored in a
variable labeled “current” while the loop is run again.

Currently the program is running in Matlab, and is written in a general form so
that, if the user wishes to change the movements from an “open to close” movement to a
“claw to close” or “claw to gun” movement, that is possible. All that is necessary are the
translational components of the vectors, beginning position joint angles, and final
position joint angles. Both the beginning and final joint angles must be stored in a three-
dimensional array in which it describes the alpha, beta, and gamma rotation angles of the
joints. Alpha, beta, and gamma rotations correspond to rotations about the Z, Y, and X
axes respectively. The translational data must be stored in a column vector that describes
the X, Y, and Z components of the link.

Once the Matlab script is running properly, the program will be paired with a
geometry machine to add texture, skin tone, and minute details that form a hand. In doing
so, as stated before, we hope to form a hand that is more convincing that previous
treatments and thereby convince the brain that the absent limb is still present and able to
move. The code will also be translated into a different computer language so that it can
be run by any compiler running that language and not Matlab alone. It will then be paired with the myoelectric device that Dr. Pierce is developing, and testing will begin.

Presently, some debugging must still be done on the initial Matlab script file that runs everything. Additional files must be created to create different hand positions, and an adequate geometry engine must be found. From there, we will work towards the ultimate goal and creating another treatment for Phantom Limb Pain that is both more effective and convincing in its presentation.


