<u>Research Assessment #3</u>

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Subject: Neuromechanical considerations for incorporating rhythmic arm movement in the rehabilitation of walking &

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Infante, Deliana. "Bionics and Neuroprosthetics: The Future of Functionality with Biomedical Engineering." *News*, 30 Nov. 2023, www.news-medical.net/health/Bionics-and-Neuroprosthetics-The-Future-of-Functionality-with-Biomedical-Engineering.aspx.

Assessment:

After reading the articles I have annotated below I believe that neuromechanical prosthetics is the path I personally want to embark on in my ISM journey so far. In the first article I learned about how they used arm movement and activity to connect it with neural variables in order to make a device that could help a human operate. I find it extremely cool how you can control the brain with a device although it does have some ethical concerns, they were talked about in the article but I want to definitely look more into that in the next research assessment. I also want to learn more about the brain after reading these articles since it picks on my curiosity. I don't really know how to explain words anymore why I am interested in this topic, I just feel it in my heart that I am. While reading these articles I wasn't overwhelmed by the amount of information I was given, in fact I wanted to take time to fully understand it and continue learning more. Usually if I don't understand something I am quick to leave it but this topic stands out from those other things since I don't feel that same way now. The closest way I can explain my interest is that it is fascinating to see how the human body reacts to certain forces that are exerted onto us. Usually you grow up thinking that my hand just does what it does because it is supposed to be doing that but we fail to realize how small components can absolutely change the way we function- and its possible to do as a human with knowledge. I want that knowledge, I am interested in learning it which is why I think neuromechanical prosthetics is the way to go. I did find a recent interest in learning more about automotive engineering but I am not sure if that is something I want to do on the side or not so that is also something I want to look into in the future research assessments. My interest in that started recently when I started driving and noticing all the cool cars around me, I don't know much about the topic but it is also something I want to look into.

*****Annotations are bolded and italicized in red with a Times New Roman font. Important information is highlighted.***

Neuromechanical considerations for incorporating rhythmic arm movement in the rehabilitation of walking

We have extensively used arm cycling to study the neural control of rhythmic movements such as arm swing during walking. Recently rhythmic movement of the arms has also been shown to enhance and shape muscle activity in the legs. ***One piece of data allowed multiple things to be studied.*** However, restricted information is available concerning the conditions necessary to maximally alter lumbar spinal cord excitability. Knowledge on the neuromechanics of a task can assist in the determination of the type, level, and timing of neural signals, yet arm swing during walking and arm cycling have not received a detailed neuromechanical comparison. The purpose of this research was to provide a combined neural and mechanical measurement approach that could be used to assist in the determination of the necessary and sufficient conditions for arm movement to assist in lower limb rehabilitation after stroke and spinal cord injury. Subjects performed three rhythmic arm movement tasks: (1) cycling (cycle); (2) swinging while standing (swing); and (3) swinging while treadmill walking (walk). We hypothesized that any difference in neural control between tasks ***would show that differences in muscle activity would show constraints applied in our body while carrying out the task– this was what they were trying to do.*** (i.e., pattern of muscle activity) would reflect changes in the mechanical constraints unique to each task. Three-dimensional kinematics were collected simultaneously with force measurement at the hand and electromyography from the arms and trunk. All data were appropriately segmented to allow a comparison between and across conditions and were normalized and averaged to 100% movement cycle based on shoulder excursion. Separate mathematical principal components analysis of kinematic and neural variables ***Basically trying to mathematically figure out how neural variables work with our body and how it helps us operate.*** was performed to determine common task features and muscle synergies. The results highlight important neural and mechanical features that distinguish differences between tasks. For example, there are considerable differences in the anatomical positions of the arms during each task ***Each part of the arm carries out a different task which moves differently kinematically.***, which relate to the moments experienced about the elbow and shoulder. Also, there are differences between tasks in elbow flexion/extension kinematics alongside differential muscle activation profiles. As well, mechanical assistance and constraints during all tasks could affect muscle recruitment and the functional role of muscles. Overall, despite neural and mechanical differences,***Even though the arm moves differently the result of arm movement with different tasks was consistent because the basic motor control mechanism of the arm is the same in all scenarios.*** the results are consistent with conserved common central motor control mechanisms operational for cycle, walk, and swing but appropriately sculpted to demands unique to each task. However, changing the mechanical parameters could affect the role ***it can change the feedback that is being given to the brain and basically do something completely different that isn't meant to happen.*** of afferent feedback altering neural control and the coupling to the lower limbs.

Bionics and Neuroprosthetics: The Future of Functionality with Biomedical Engineering

The intersection of biology and technology

Biomedical engineering, the convergence of medicine, biology, and engineering, has evolved over the years in response to advances in science and technology.

From the creation of the first kidney dialysis machine to the development of artificial limbs, biomedical engineering has made significant strides in improving the quality of life for many people.

Bionics and neuroprosthetics are key to these advances. These disciplines are closely linked to the development of microsystems technology, nanotechnology, information technology, biotechnology, and the application of new materials. These devices use electrical stimuli to stimulate neural structures to support, augment, or partially restore the impaired or lost function.

The science of bionics and neuroprosthetics

The foundation of bionics and neuroprosthetics is the seamless integration of biological systems with artificial mechanisms. By exploiting principles such as biocompatibility and neuroplasticity, researchers have successfully developed biomedical products that mimic natural body functions. Notable examples include Cochlear implants, retinal implants, and prosthetic limbs.

Cochlear implants work by converting sound into electrical signals that stimulate the auditory nerve directly, bypassing damaged ciliated cells, and retinal implants convert light into electrical signals that travel through the optic nerve.

Advanced prosthetic limbs have also made significant advances in mimicking natural movement. They use sensors, microprocessors, and myoelectric technology that the user's own neural signals can control.

One example is the e-OPRA implant system developed by Integrum AB. It attaches the prosthetic arm to the bone in the amputated stump, and electrodes implanted in the muscles and nerves of the amputated arm, along with an embedded connector, create an electrical interface. These electrodes connect to sensors in the body through the Integrum control system in the prosthesis. By transmitting sensory input from the prosthesis back to the user, they can control its movement.

All of these prostheses and devices operate through neural interfaces, which are the fundamental link between the biological system and the machine. Several types of neural interfaces are currently in use. Brain-computer interfaces (BCIs) are one of them.

BCIs provide a direct link between the brain and an external device, allowing individuals to control devices using their neural signals. BCIs can use invasive or non-invasive techniques such as electrocorticography (ECoG) or electroencephalography (EEG). They have shown promise in assisting people with amyotrophic lateral sclerosis, cerebral palsy, stroke, or spinal cord injury.

Other approaches include peripheral nerve interfaces, which connect peripheral nerves to the prosthetic limb to allow bidirectional communication. Techniques such as targeted muscle reinnervation (TMR) reroute nerves to activate specific muscles, allowing users to control the prosthesis more intuitively.

Finally, optogenetics-based interfaces are another promising neural interface. Optogenetics combines genetic engineering and light-sensitive proteins to control neural activity using light. This technique has shown potential for modulating neural circuits and restoring function in animal models, but its clinical application is still in the early stages of research.

Achievements and milestones

There are several successful case studies of patients benefiting from bionics and neuroprosthetics. One of the most recent examples is the case of a 27-year-old patient with unilateral obstetric brachial plexus injury (OBPI). People with severe OBPI typically face significant limitations in their daily lives due to limited hand-arm function, and traditional reconstructive methods often fail to restore their use.

This patient underwent bionic reconstruction, including elective amputation, humeral de-rotation osteotomy, and myoelectric prosthetic fitting. Functional assessments and self-reported questionnaires showed significant improvement in hand function and independence in daily activities.

Another example is the research conducted by the Cleveland Clinic in 2021, where researchers developed a groundbreaking neurorobotic prosthetic arm for upper extremity amputees. This bionic system enhanced the wearer's ability to think, behave, and function much like a person without an amputation. Combining intuitive motor control, touch, and grasp kinesthesia, the prosthetic arm provided bidirectional feedback and control.

Two participants with upper limb amputations who had undergone targeted sensory and motor reinnervation successfully tested the bionic limb, achieving a level of accuracy comparable to non-disabled individuals. These studies demonstrate the significant impact that advances in these areas can have on improving patients' quality of life.

Challenges and ethical considerations

Despite their significant advances, these fields still face several challenges and limitations. One of the main challenges is the specificity of the feedback provided by these devices. Patients often experience irritation or shock-like sensations, which can be a barrier to the successful implementation of these technologies.

In addition, there are health risks associated with implanting any device in the body, as these devices affect the neural wiring of the individual.

In addition, the long-term viability and biocompatibility of stimulation electrodes, the selection of appropriate strategies for each patient, and a better understanding of brain plasticity are some of the technical and biological challenges that remain to be overcome.

The rapid advances in bionics and neuroprosthetics also raise several ethical concerns. For example, there are issues related to informed consent, especially for patients with locked-in syndrome.

Privacy and security issues are other areas of concern. Therefore, it's important to balance the potential benefits of these technologies with their ethical implications.

Companies paving the way

Several companies are contributing to the advancement of bionics and neuroprosthetics. Some of them are Medtronic PLC, Edward Lifesciences Corporation, Ekso Bionics and Ossur (Touch Bionics), LivaNova PLC, Demant A/S, Cochlear, and NeuroPace Inc.

Today, Medtronic is the global leader in this industry due to its extensive global presence, innovative solutions, and significant investment in research and development. The company operates in 160 countries, providing treatments for more than 70 medical conditions.

Medtronic has developed a broad range of products, including deep brain, spinal cord, and peripheral nerve stimulation systems. In terms of future developments,

Medtronic has shown its desire to create new solutions to treat a wider range of health conditions.

This briefly shows the great impact and presence these companies have in the healthcare industry and how they continue to innovate with ongoing research and development efforts to create better solutions for patients with disabilities.