NEUROPROSTHETICS IN THE 21ST CENTURY AND BEYOND

AN ECO-SYSTEM WITH A DIFFERENCE

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The fast-paced field of neuroscience encapsulates an array of highly intelligent scientists, engineers, surgeons and neurologists. Over the last twenty years' advances in technology and innovation has seen machines, robotics and interfaces develop at a startling rate as more is learnt in neuroscience (Bensmaia & Miller, 2014). Interestingly, an article entitled *Defining Ecological Strategies in Neuroprosthetics,* argues that the advances in technology are hindering the progress in neuroprosthetics due to the lack of clinical dissemination (Courtine & Bloch, 2015).

While most of us agree that technological innovations are essential for progress in specialized fields of science, the authors, Courtine and Bloch (2015) contend three main difficulties; that the bulky machinery and interfaces are a hindrance and a waste of resources; the professional care providers are not educated in how to effectively employ the use of the neuroprosthetic treatment and the machines are impersonal to the patient and standardized.

Courtine and Bloch (2015) devised an analogy in their approach of awareness and sustainability of therapeutic developments through ecological strategies. Understanding what an ecology is and how it is sustained is paramount to reflecting on the similarities of the human ecological system.

An ecology is a habitat which is arranged in vertical and horizontal stratifications. These stratifications are autonomous and interdependent. By envisioning our central nervous system (CNS) as a complex neuro- ecosystem, we can form a correlation of both stratifications (Courtine & Bloch, 2015). The vertical stratification consists of the CNS which has local neural circuits and the horizontal plane resembles the brain, spinal cord and peripheral nervous system (Courtine & Bloch, 2015). These have long distance connectors; like a forest ecology (Courtine & Bloch, 2015). The concept is unique.

Within our environment ecological strategies help maintain a balance across the habitat. This is accomplished by a principle referred to as the 'Three R's'. Reuse, Recycle and Reduce. These principles have helped preserve our natural environment. Can the same principles be employed as strategies to implement and sustain ongoing therapeutic developments in Neuroprosthetics?

Courtine and Bloch (2015) think so. Their ideas for 'reuse' rely on functional neural circuits and connections being reorganized to establish balance within the brain ecosystem by employing brain-machine interface (BMI). Neuromodulation therapies, also, reuse spare circuits although functional benefits remain elusive as more research and investigation is needed (Courtine & Bloch, 2015).

The second 'R' relates to recycle. Similar to 'reuse', Courtine and Bloch (2015), suggest being able to recycle energy into neural circuits, spare circuits and connections would need to be utilized in order to recalibrate the unbalanced ecosystem. This is performed through deep-brain stimulation (DBS) which involves surgically implanting electrodes into the brain. The device sends electrical impulses through electrodes in the brain and is controlled by a device similar to a pacemaker located in the patient's chest region. This technology helps to improve the patient's quality of life (Mayo Clinic, 2016).

Reduce is the third 'R'. The advice to reduce and refine current technological treatments will improve clinical impacts which will be passed on to patients (Courtine & Bloch, 2015). Over the last fifteen years' technology has improved the effectiveness and comfort of patients through infrastructure to charge batteries in clinics and homes, improved development in algorithms, reduction of implant size and many more revolutionizing innovations (Courtine & Bloch, 2015). According to the authors, less new innovations are needed; however, more investments in research, time and money are the key (Courtine & Bloch, 2015).

A recent article in New Scientist tells the story of a young man, Ian Burkhart, who broke his neck when diving into a shallow waterhole on holiday (Hamzelou, 2016). The young man is a quadriplegic. Neuroscientists Dr. Ali Rezai and Dr. Chad Bouton, along with their colleagues, worked closely with Mr. Burkhart. Through mind mapping technology, deep brain stimulation and surgery they could help Mr. Burkhart regain control of his hand and fingers. This technology is still in the beginning stages but researchers have plans to develop external electrodes to control limbs, making the procedure less invasive for the patient.

Research is striving to advance and enhance the quality of life for patients with neuromuscular disease, spinal cord injuries and strokes. An article, penned by John F Kalaska (2008), informs us that patients who suffer from ill-fortune still have the ability to produce the brain activity required to perform movements. 'Reuse', as spoken of by Courtine and Bloch (2015), is an idea reflected in several papers including an empirical paper entitled *High-performance neuroprosthetic control by an individual with tetraplegia* (Collinger et al,2016). This paper relates investigative findings of a 52-year-old woman who suffers from spinocerebellar degeneration. The aim of the investigation was to test if an individual with tetraplegia could control and use a high-performance limb by achieving neurological control by using the technology of BMI (Collinger et al, 2016). The findings indicated that the subject could skillfully use the prosthetic limb with coordination in movements such as reach and grasp (Collinger et al, 2016). This implies that with future developments in technology neuroprosthetic limbs will allow individuals to perform everyday tasks restoring their quality of life (Collinger et al, 2016).

Courtine and Bloch’s (2015) article may have been biased toward research and further learning however technology enhances the ability to learn. The blended relationship between science and technology makes it hard not to interchange the two. For instance, without science we wouldn’t have technology and vice versa. From early days, our culture has been driven by technology and the progression of these innovations followed allowing for development of intellectual theories and investigations.

The three challenges of ‘reuse, recycle and reduce’ facing neuroprosthetics are considerable nonetheless opportunities have opened the way for further growth and improvement (Bensmaia & Miller, 2014). This analogy reveals the importance of the underlying problems related to the direction, education and purpose neuroscience and neuroprosthetics must heed (Courtine & Bloch, 2015). Knowledge of fundamental errors in technology, including BMI and neuromodulation therapies, and a lack of clinical dissemination are recognised in journal reviews however, developments in the field are continuing and showing potential in all the specialties of neuroprosthetics (Bensmaia & Miller, 2014). As Figure 1 depicts the importance of advancing technology is within the clinical dissemination of the product. With the clear objective of ‘quality of life’ for patients and their families neuroprosthetics can move forward at a compassionate rate.

Figure 1: This picture captures the essence of quality of life for patients and carers confirming that clinical dissemination of knowledge, products and software is of high importance.

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