APPLIED SCIENCES WEBINAR SERIES

BIOELECTRONICS

POST WEBINAR HANDOUT 1 - PROFESSOR ALISTAIR MCEWAN

Thank you for attending our Applied Sciences Webinar! Here's a quick recap of some of the highlights and some further reading you might be interested in.

HOMEGROWN DEVICES

There are so many ways we incorporate electrical devices into medical practice. Some have been developed in Australia, and have revolutionised medicine:

1928: A prototype for today's pacemakers was used to restart a stillborn infant's heart at the former Crown Street Women's Hospital, Sydney

1961: The Grey Scale Ultrasound was pioneered in the research labs of Sydney, allowing clear and detailed imaging inside the body

1979: The modern multi-channel cochlear implant was independently developed by teams at the University of Melbourne and the University of Vienna, providing those with sensorineural hearing loss a way to perceive sound

CEREBRAL PALSY

Cerebral palsy is a movement disorder, and is the most common physical disability in childhood. While there are no cures, treatments such as electrically stimulating the spinal cord show potential, as they also do for stroke or spinal cord injuries.

In some cases, people regain their ability to walk even after stimulation has stopped!

EMERGING BIOTECHNOLOGY

There are also many creative ways that biotechnologies are being used:

- Microwave ablation is a technique used to heat and remove unwanted body tissue. Much like your microwave oven at home, it can heat things without needing to physically be in contact with the tissue!

Using it to remove nerves near the kidney's arteries is an effective way to treat high blood pressure, producing more consistent results than standard radioablation techniques which have a whole host of limitations.

- Sonification, in the context of electroencephalography (EEG), is the process of turning electrical signals into sound waveforms, which allows the quick detection of rhythmic EEE problems in real-time.

Some Further Reading

https://www.braingate.org/

- Braingate develops and tests new medical devices which restore function to those affected by neurological disease, paralysis, or limb loss.

Russo, M., Cousins, M., Brooker, C., Taylor, N., Boesel, T., & Sullivan, R. et al. (2017). Effective Relief of Pain and Associated Symptoms With Closed-Loop Spinal Cord Stimulation System: Preliminary Results of the Avalon Study. Neuromodulation: Technology At The Neural Interface, 21(1), 38-47. doi: 10.1111/ner.12684

- Electric devices that are similar to cochlear implants can be used for reducing back pain! This specific one is being developed here in Sydney.

APPLIED SCIENCES WEBINAR SERIES

MICRONEUROGRAPHY

POST WEBINAR HANDOUT 2 - PROFESSOR VAUGHAN MACEFIELD

Thank you for attending our Applied Sciences Webinar! Here's a quick recap of some of the highlights and some further reading you might be interested in.

MICRONEUROGRAPHY

Microneurography was developed in the mid '60s by Karl-Erik Hagbarth and Åke Vallbo. It uses micro electrodes to record nerve impulse traffic in both peripheral and cranial nerves.

It enables the recording impulses from nerves 1/5th the diameter of a human hair, including muscle spindles which are our primary proprioceptors!

Recently, advances in microneurography have been made - we can now record the activity of the vagus nerve by using electrodes inserted into the neck.

Macefield works with microneurography techniques to:

- Record the activity of sympathetic neurons that supply the skin and muscles.

- Combine it with fMRI, allowing the activity of particular neural regions in patients with obstructive sleep apnea to be monitored.

DID YOU KNOW?

Contrary to many textbooks, 80 m/s is the fastest nerve impulse speed in humans; the 120 m/s quoted comes from cat nerves.

NEURO AMP EX

Neuro Amp Ex is a signal processing unit integral to microneurography research.

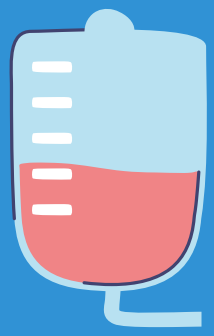
What does it do?

- It pre-amplifies the nerve signals before they reach the main signal processing unit to reduce interference from electrical noise in the surrounding environment.
- Entirely stainless steel design allows its use in conjunction with magnetic resonance technologies such as fMRI - a key application!

MSNA-COUPLED FMRI

Sympathetic nerves in muscles were stimulated in healthy young patients and those with obstructive sleep apnea. The data collected revealed coupling between different brain regions, implicating they are involved in sympathetic nerve activity.

What was found?



- The dorsolateral prefrontal cortex (dlPFC) is involved in the regulation of blood pressure. This helps explain the role of stress in blood pressure.
- Rostral ventrolateral medulla (the primary output area of sympathetic nerve activity) is functionally coupled to many regions in the brain including the ventromedial hypothalamus, dlPFC and the anterior insula.

These give further evidence to the top-down control structure of the brain, which allows higher order regions to influence regions. Together, they control homeostasis in the body.

What does this mean for us?

Well, this explains the physiological changes of:

- Decreases in blood pressure one undergoes due to emotional response, e.g. listening to music

Some Further Readings

El Sayed, K., Macefield, V., Hissen, S., Joyner, M., & Taylor, C. (2018). Blood pressure reactivity at onset of mental stress determines sympathetic vascular response in young adults. Physiological Reports, 6(24), e13944. doi: 10.14814/phy2.13944

Henderson, L., Fatouleh, R., Lundblad, L., McKenzie, D., & Macefield, V. (2016). Effects of 12 Months Continuous Positive Airway Pressure on Sympathetic Activity Related Brainstem Function and Structure in Obstructive Sleep Apnea. Frontiers In Neuroscience, 10. doi: 10.3389/fnins.2016.00090

Fatouleh, R., Hammam, E., Lundblad, L., Macey, P., McKenzie, D., Henderson, L., & Macefield, V. (2014). Functional and structural changes in the brain associated with the increase in muscle sympathetic nerve activity in obstructive sleep apnoea. Neuroimage: Clinical, 6, 275-283. doi: 10.1016/j.nicl.2014.08.021

Knellwolf, T., Burton, A., Hammam, E., & Macefield, V. (2018). Microneurography from the posterior tibial nerve: a novel method of recording activity from the foot in freely standing humans. Journal Of Neurophysiology, 120(3), 953-959. doi: 10.1152/jn.00937.2017

APPLIED SCIENCES WEBINAR SERIES

THE BIONIC EYE

POST WEBINAR HANDOUT 3 - PROFESSOR GREGG SUANING

Thank you for attending our Applied Sciences Webinar! Here's a quick recap of some of the highlights and some further reading you might be interested in.

BACKGROUND - NEUROMODULATION

Neuromodulation is the alteration of the activity of nerve cells through electricity.

At the synapse, nerve cells send signals to one another by releasing chemicals – this results in a relay of information.

Alessandro Volta, the inventor of the electric battery, discovered that electrical stimulation in the ear can create a perception of sound. He described the sensation as "jolt to the head followed by the sound of thick soup boiling."

BIONIC EYE

There are currently two targets for the bionic eye:

- Retinitis Pigmentosa is a rare genetic disorder in young people that results in the breakdown of photoreceptors in the retina. It often begins with the loss of peripheral vision.

- Age-related Macular Degeneration affects the macula, located in the centre of the retina. It results in the loss of central vision.

The diseases on the previous page leave behind an intact optic nerve, which makes implants targeting the nerve still viable.

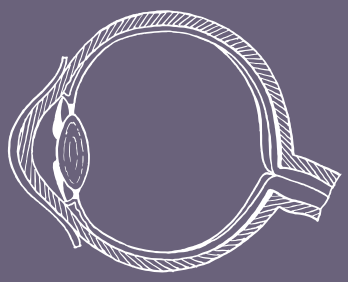
Other possible points for intervention include

- Optic nerve
- lateral geniculate nucleus (invasive)
- The visual cortex

RETINAL LAYERS

1. Nerve fibre layer - *axons of ganglion cells which leave retina in optic nerve*
2. Retinal ganglion cells- *end point of neuronal network*
3. Inner plexiform layer - *synapses bipolar cells to ganglion cells and amacrine cells*
4. Inner nuclear layer - *nuclei of bipolar, horizontal and amacrine cells*
5. Outer plexiform layer - *synapses photoreceptors to bipolar cells and horizontal cells*
6. Outer nuclear layer - *nuclei of photoreceptors*
7. Photoreceptor layer - *outer and inner segments of rods and cone*
8. Retinal pigment epithelium – *contain pigmented epithelial cells that absorbs light and supports retinal visual cells*

In the case of retinitis pigmentosa and macular degeneration, the photoreceptors die. However it is possible to start a signal by stimulating the bipolar and retinal ganglion cells.



The retinal prosthesis can be placed in the suprachoroidal area, placing it further away* from the retinal ganglion and bipolar cells.

This means that local reactions to the foreign device being placed does not damage the remaining nerve cells; a similar concept used in cochlear implants!

*Placed further away = need a slightly stronger signal to stimulate nerve cells

SUANING & TEAM'S IDEA (PHOENIX99)

- Small burst of electricity supplied by an implant placed behind the ear (inductor) - data is transmitting from here and will not need to be placed under the skin.
- These electrical bursts are sent to another implant placed behind the eye.
- The electrical impulses are then passed down to the V1 area of the brain.

WHERE ARE WE NOW?

The bionic eye was initially implanted in human cadavers, then in sheep.

A heat-map of cortical activation can be used to show that the sheep were getting visual information from the bionic eye, allowing us to test that it is actually working.

Currently, the implant is in the testing phase:

- Ethics approval - a lot of testing is required before they can safely insert the implant (so people aren't negatively affected)
- Patients with even a little bit of function are excluded from experimental trials to not risk making their condition worse

Some Further Reading

Suaning, G., Lovell, N., & Lehmann, T. (2014). Neuromodulation of the retina from the suprachoroidal space: The Phoenix 99 implant. 2014 IEEE Biomedical Circuits And Systems Conference (Biocas) Proceedings. doi: 10.1109/biocas.2014.6981711

Suaning, G., Lovell, N., Schindhelm, K., & Coroneo, M. (1998). The bionic eye (electronic visual prosthesis): A review. Australian and New Zealand Journal of Ophthalmology, 26(3), 195-202. doi: 10.1111/j.1442-9071.1998.tb01310.x

APPLIED SCIENCES WEBINAR SERIES

MENTAL HEALTH & PSYCHOLOGY

POST WEBINAR HANDOUT 4 - DR SUSANNE SCHWEIZER

Thank you for attending our Applied Sciences Webinar! Here's a quick recap of some of the highlights and some further reading you might be interested in.

WHY IS MENTAL HEALTH AN ISSUE?

Rates of psychiatric morbidity have increased over time. Mental illness and suicide are estimated to have cost the Australian economy **$43-51 billion** in 2018-19. Accessing treatment and specialist services is often difficult and associated with lengthy waiting times.

Additionally, many treatments and therapies only have an efficacy rate of ~60%. For young people, loss of productivity due to mental health conditions is particularly important as they lose a lot of time that could have been spent learning useful skills.

TREATING MENTAL HEALTH

Treatment needs to be targeted at an aspect that is modifiable and with many downstream effects.

Ideally, it will also be **transdiagnostic**, meaning that the process targeted is associated with many potentially comorbid disorders. This will ensure its efficacy for a wide range of individuals.

DR SUSANNE SCHWEIZER'S RESEARCH

Dr Schweizer focuses on affective control, which is the cognitive mechanism underlying emotional regulation with relation to task goals. Good affective control means that individuals are able to focus on the task at hand regardless of emotional distractors, whether they be positive or negative.

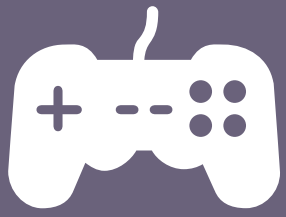
Her research suggests that poorer affective control can impact an individual's multitasking ability, working memory and higher order cognition when they are distracted by negative emotional stimuli.

APPLICATIONS OF EMOTIONAL WORKING MEMORY TRAINING

Structures such as the **amygdala** and **fusiform gyrus** are involved in emotional processing. Studies found **decreased activation of emotional processing areas** when individuals with emotional working memory training performed simple working memory and operational tasks involving negative emotional stimuli.

Individuals who have had emotional working memory training still reacted to negative stimuli but became **better at regulating their emotional response**.

If brain training can increase affective control, it could be a potential therapeutic option for individuals with conditions such as PTSD.



Incorporating emotional working memory training in downloadable games and apps may be useful for improving affective emotional control in adolescents with trauma.

Some Further Reading

Schweizer, S., & Dalgleish, T. (2011). Emotional working memory capacity in posttraumatic stress disorder (PTSD). Behaviour Research And Therapy, 49(8), 498-504. doi: 10.1016/j.brat.2011.05.007

EMOTIONAL WORKING MEMORY CAPACITY IN PTSD

This study investigated the effect of negative and neutral distractors when performing an operational task (evaluating sentence syntax) and a storage task (word memorising).

Individuals who have undergone trauma tend to use negative sentences and have negative thoughts, which contributes to the mental disorder. Hence, they are less likely to recognise the difference between negative and neutral stimuli sentences.

Schweizer, S., & Dalgleish, T. (2016). The impact of affective contexts on working memory capacity in healthy populations and in individuals with PTSD. Emotion, 16(1), 16-23. doi: 10.1037/emo0000072

THE IMPACT OF AFFECTIVE CONTEXTS ON WORKING MEMORY CAPACITY IN HEALTHY POPULATIONS AND IN INDIVIDUALS WITH PTSD

This study followed a similar structure having individuals respond to neutral and negative images, aiming to look at the impact of visual stimuli upon visuospatial task performance.

In most individuals, having negative images as a distractor resulted in a lower score when performing operational tasks such as counting shapes. However, individuals with PTSD tended to have a significantly greater difference in score when distracted by negative images. This suggests that those with PTSD are more severely affected by negative images than the general population.