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No Advisor Assigned
Cognitive Testing of Non-Human Primates
Electroencephalography Techniques for Cognitive Testing

Introduction

Electroencephalography provides an effective method for cognitive measurement in both humans and non-human primates. It is noninvasive, using electrodes placed on the scalp to measure voltage fluctuations resulting from ionic currents within neurons in the brain. It can measure overall processing flow between sections of the brain but does not provide insight into individual buses of information between neurons. This is sufficient, however, to identify to what degree each section of the brain is active and whether abnormal oscillations, like those found in epilepsy patients, is present [1]. The first systematic study of EEG potentials was conducted in 1912 by Ukrainian physiologist Vladimir Pravdich-Neminsky, and ever since then EEG has played a crucial rule in brain analysis. Edgar Allen, for instance, used this technology to describe the REM sleep cycle in humans in 1935, and it is standard practice to use EEG for a variety of applications in modern neurology [1].

Basic Function

The brain is comprised of a network of billions of neurons, which are electrically charged by membrane transport proteins. When neurons discharge ions through this mechanism, there is a chance that they will push charged material in a wave towards the scalp, where they can be identified by external electrodes on the skull. [2]. Typically, these waves occur in specific frequencies corresponding to a variety of activities. For instance, the alpha wave oscillations, occurring at about 10 Hz, correlate strongly with relaxation and the early onset of sleep.

In order to measure these potentials, electrodes are placed on the scalp with a conductive gel, typically in the international 10-20 system [3]. In this setup, 19 recording electrodes are used along with ground and a uniform system reference. It is important that this setup is followed as closely as possible because each channel corresponds to a specific part of the brain, and the 10-20 system allows results to be easily read regardless of who is conducting the experiment. Each of these electrodes is connected to the input of a differential amplifier, and the system reference connected to the other input [3]. Typical systems seek to achieve 60-100 db gain before filtering through an anti-aliasing filter [3]. This eliminates problems occurring from sampling below the Nyquist rate and increases the signal to a level readable by an analog to digital converter. The typical analog to digital sampling rates for clinical EEG are around 256-512 Hz [3]. It is also recommended to incorporate low and high pass filters set to cutoff signals

below 1 Hz and above 70 Hz respectively [4]. These filters eliminate not only noise, but also electro-galvanic and electromyographic signals, which are not considered in cognitive testing. Once the signals have been converted to a digital signal, they are then typically classified with a machine learning algorithm, like the EEGLAB or Neurophysiological Biomarker Toolbox, both of which are available as open source packages [4]. These packages can be set to identify a variety of conditions and states of mental activity, like processing of images through steady state visually evoked potentials [5].

There are, however, several limitations to current EEG technology, although much research is being conducted at places like the Yeo Group at Georgia Tech to overcome these difficulties. First, there is a large bias towards dendritic as opposed to axonal currents, and almost all recordings are dominated by parallel dendrites and pyramidal neurons [6]. These are, however, representative enough of the whole signal that they are typically sufficient for diagnosing purposes. Of more concern is smearing of the signal resulting from cerebrospinal fluid, which introduces significant noise [6]. If high resolution EEG is required, surgery is required to bypass this fluid, although much effort is being expended to create a nonsurgical solution. There are also inverse currents that cancel each other out, so it is impossible to accurately recreate the full image of neural activity between larger sections, even if the fluid is bypassed [6]. Despite these limitation, EEG remains a highly effective means of identifying and classifying neural activity.

Current Products on Market

EEG devices vary widely in price based on their specific purpose. In the Yeo Group, we designed and constructed EEG systems using dry gold electrodes, manufactured by hand in an aerosol jet printer, basic differential amplifiers, an nrf52 PCA10065 chip with Bluetooth capabilities, and the MATLAB machine learning package. This provided significant cost savings, but would not be suitable for a hospital application, where advanced integrated electronics are required. Typical systems can range from $800 for home use style systems to $20,000 for full functionality hospital equipment. The Australian company Neuroscan is one of the most respected companies providing EEG systems on the market today, and they have a proven track record of success dating back to 1985 [7]. They provide the entire package for a full EEG system, including amplifiers, electrodes, digitization packages, and data analysis software. Typical prices for their equipment is around $15,000.

There are, however, plenty of competitors on the market today, like the German company Brain Products. They opt to use open source software packages and instead focus on high density measurements, using up to 160 channels [7]. They are more suited to research applications and highly skilled neurologists as a result because the 10-20 system is not used. The price range for these devices is similar to that offered by Neuroscan.

Another competitor that provides high grade research capable EEG packages at a more affordable price is the Dutch company BioSemi. They specialize in high quality research applications that are highly customizable for greater versatility but require more effort and learning to properly configure. They also are not limited to the conventional 10-20 system [7].

Conclusions

EEG provides the most accurate method to date for classifying brain activity in humans and non-human primates, despite having several minor limitations. Although expensive professional systems are readily available on the market today, it is much more economical to design the systems oneself specifically for the task required. This can be readily done with basic equipment and access to an aerosol jet printer to print the electrodes. Therefore, it is highly recommended that EEG be used to for cognitive testing of non-human primates.

Works Cited

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