Neural signal

A neural signal is another way of characterizing the electrochemical message that neurons send to each other.

When a neuron receives sufficient stimulation in the form of EPSPs, voltage-gated ion channels open, and a signal is sent down the axon to the axon terminal. That is the electrical part of the message.

The chemical part of the neural signal is the more complicated part, and it is what makes the brain far more complicated than the 1s and 0s used in analog. An action potential causes voltage-gated calcium ion channels to open in the axon terminals, and a chemical called a neurotransmitter is released into the synapse.

Binary is incredibly inferior when compared to the complexity of the chemical component of the neural signal. There are countless numbers of neurotransmitters and receptors, each having a unique and different effect on post-synapatic neurons. Each neurotransmitter can have many different types of receptors that each have different effects.

And to complicated things even more, the two main types of receptors, ionotropic and metabotroptic, have vastly different effects. Ionotropic receptors act quickly, influencing the firing of action potentials directly. But metabotropic receptors act slowly via protein cascades and influence gene expression, often changing the number of receptors. That increases the complexity greatly.

Simplifying things by saying neurons are either “on or off” is a mistake. I think the brain is far more complicated than even a hypothetical 0-8 system.

Consider the fact that neurons are constantly changing, the synapses are moving and dynamic. What your brain looked like yesterday is not what it looks like today. It is the dynamic nature of neurons that make them superior to binary. Can a computer change it's own wiring? No, it can't.

So yes, a neural signal can be interpreted as information, but not in the same simple way that computers and CDs have information. Subtleties can't be ignored when we are talking about biology, especially in regards to something we don't fully understand yet. The brain is far more complicated than any computer system we have to date, so we really shouldn't do it a disservice by over-simplifying it's signals.

Conventional neural signal analysis methods assume that features of interest are linear, time-invariant signals confined to well-delineated spectral bands. However, new evidence suggests that neural signals exhibit important non-stationary characteristics with ill-defined spectral distributions. These features pose a need for signal processing algorithms that can characterize temporal and spectral features of non-linear time series. This study compares the effectiveness of four algorithms in extracting neural information for use in decoding cortical signals: Fast Fourier Transform bandpass filtering (FFT), principal spectral component analysis (PSCA), wavelet analysis (WA), and empirical mode decomposition (EMD).

Approach: Electrocorticographic signals were recorded from the motor and sensory cortex of two epileptic patients performing finger movements. Each signal processing algorithm was used to extract beta (10-30 Hz) and gamma (66-114 Hz) band power to detect thumb movement and decode finger flexions, respectively. Naïve-Bayes (NB), support vector machine (SVM), and linear discriminant analysis (LDA) classifiers using each signal were validated using leave-one-out cross-validation.

Main results: Decoders using all four signal decompositions achieved above 90% average accuracy in finger movement detection using beta power. When decoding individual finger flexion using gamma, the PSCA NB classifiers achieved 78 ± 4% accuracy while FFT, WA, and EMD analysis achieved accuracies of 73 ± 8%, 68 ± 7%, and 62 ± 3% respectively, with similar results using SVM and LDA.

Significance: These results illustrate the relative levels of useful information contributed by each decomposition method in the case of finger movement decoding, which can inform the development of effective neural decoding pipelines. Further analyses could compare performance using more specific non-sinusoidal features, such as transients and phase-amplitude coupling [1].

1)

Duraivel S, Rao AT, Lu CW, Bentley JN, Stacey WC, Chestek CA, Patil PG. Comparison of signal decomposition techniques for analysis of human cortical signals. J Neural Eng. 2020 Oct 13;17(5):056014. doi: 10.1088/1741-2552/abb63b. PMID: 33047675.