Frequency-dependent plasticity: The reshaping of oscillatory networks by entrainment

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Overview

Brain oscillations and inter-regional synchronization are essential for sensory and cognitive processing, learning, and motor coordination. Abnormalities in synchronization are associated with neuropsychological and neurodegenerative conditions. Restoring the deficient synchronization by entrainment to rhythmic sensory/electric stimulation recovers the associated functionality. Furthermore, Evidence suggests that the dominant spectral feature characteristics of a (sub)network emerge from the connectivity structure of the network.

On the other hand, rhythmic events are ubiquitous in the natural sensory environment, e.g., streams of meaningful speech or music fluctuate over slow rhythms. Neurophysiological and imaging evidence show that when endogenous brain oscillations are entrained (phase-aligned) to an external sensory stream fluctuating at the preferred frequency, meaningful events are processed and perceived more efficiently, and brain networks are strengthened. Conversely, neuroplasticity and learning mechanisms are activated when the sensory information is embedded in a novel un-preferred frequency. In other words, and regardless of the sensory modality, neural entrainment to the environment is crucial for structuring incoming information streams for further processing, including discrimination, attention selection, coupling to motor output, and, crucially, learning. For example, visual and auditory alpha stimulation can be analgesic, delta beats aid pacing in Parkinson's, theta electric stimulation improves associative memory, and electric gamma stimulation improves reading accuracy in dyslexia. However, the lack of mechanism(s) by which sensory (or electric) stimulation changes brain function leads to ad-hoc implementation with unknown long-term consequences and speculation about the effects.

The presentations of this symposium are designed to be interlinked, leading to the argument for a systematic approach relating neurostimulation parameters to a specific network-oscillation pairing, which in turn maps onto one particular task:
**Cabral, Otero, and Guevara [Frequency properties of large-scale biophysical models of oscillatory brain networks] will use biophysical models to make a case for emergent synchronisation properties due

to the interaction between intrinsic population frequencies and network topography and connection delays.
**Negron, Fuentealba, and Herrmann [Task-Network-Frequency specificity: human evidence and the view from animal models] will present data on the specificity of the trio network-oscillation-task in humans and rodents.
**Lea-Carnall, Herrmann, and Stagg [Frequency dependent entrainment and plasticity] will present evidence of the neurophysiological and neurochemical mechanisms that underpin frequency-dependent entrainment and plasticity.

Lecture 1: *Spectral properties of large-scale biophysical models of oscillatory brain networks*
Joana Cabral Presenter

Joana Cabral; Monica Otero; and Pamela Guevara
will use biophysical models to make the case for emergent spectral properties as a result of the interaction between intrinsic population frequencies and network topography and connection delays. The aim is to show that functional networks have frequency characteristics that makes them sensitive to a particular information stream.

Lecture 2: *Task-Network-Frequency specificity: human evidence and view from animal models*
Ignacio Negron Presenter

Ignacio Negron, Pablo Fuentealba and Christoph Herrmann
This talk will present data on the specificity of the network-oscillation-task interaction in humans and rodents. The aim is to show that a functional network is recruited, it has a specific spectral features, to support a specific task.

Lecture 3: *Frequency-dependent entrainment and plasticity*
Charlotte Staff Presenter

Caroline Lea-Carnall; Christoph Herrmann and Charlotte Stagg
Will present evidence of the neurophysiological and neurochemical mechanisms that underpin frequency-dependent entrainment and plasticity.