The Phase-Locking Value (PLV) is a statistical measure used in signal processing and neuroscience to quantify the degree of phase synchronization or phase coherence between two or more time series signals. It is particularly valuable in the analysis of oscillatory neural activity, such as electroencephalogram (EEG) or magnetoencephalogram (MEG) data, where researchers seek to understand how different regions of the brain synchronize their activity.

Here's how the Phase-Locking Value is computed and what it signifies:

Phase Information: First, the signals of interest are typically transformed into their phase representations. For example, in the context of EEG or MEG data, this might involve applying a mathematical operation like the Hilbert transform to extract the instantaneous phase of the oscillatory components at specific frequencies.

Phase Difference Calculation: Once the phase information is obtained, the phase differences between the signals of interest are calculated. This is done by subtracting the phase of one signal from the phase of another at each time point.

PLV Computation: The Phase-Locking Value is computed by taking the absolute value of the average of the complex-valued exponential of the phase differences over time. Mathematically, it can be expressed as:

PLV = |1/N Σ e^(iΔφ)|

where N is the number of time points, Σ represents summation over time, i is the imaginary unit, and Δφ represents the phase difference at each time point.

Interpretation: The resulting PLV value ranges from 0 (no phase locking or synchronization) to 1 (perfect phase locking or synchronization). A PLV of 0 indicates that the phases of the two signals are unrelated or independent, while a PLV of 1 suggests that the phases are tightly synchronized or locked together.

Applications of the Phase-Locking Value (PLV) include:

Neuroscience Research: Researchers use PLV to study neural connectivity and functional interactions between different brain regions. It helps in understanding how brain networks communicate and synchronize their activity during cognitive tasks or in various neurological and psychiatric conditions.

Electrophysiological Studies: PLV is often employed in EEG and MEG studies to investigate the coordination of neural oscillations at different frequency bands. It can provide insights into the neural mechanisms underlying various cognitive processes.

Clinical Applications: PLV analysis can be used in clinical contexts to assess brain function and connectivity in patients with neurological disorders, such as epilepsy, Alzheimer's disease, and schizophrenia.

Brain-Computer Interfaces: PLV analysis can contribute to the development of brain-computer interfaces (BCIs) by providing information about the synchronization of neural activity patterns that can be used to control external devices.

In summary, the Phase-Locking Value (PLV) is a valuable tool for quantifying phase synchronization or coherence between oscillatory signals, particularly in the field of neuroscience where it helps researchers study brain connectivity and functional interactions.

A study aimed to identify a sensitive and specific biomarker to detect Loss of control (LOC) onset for DBS. They hypothesized that changes in phase-locking value (PLV) predict the onset of LOC-associated cravings and distinguish them from potential confounding states.

Using DBS data recorded from the nucleus accumbens (NAc) of two patients with binge eating disorder (BED) and severe obesity, we compared PLV between inter- and intra-hemispheric NAc subregions for three behavioral conditions: craving (associated with LOC eating), hunger (not associated with LOC), and sleep.

Results: In both patients, PLV in the high gamma frequency band was significantly higher for craving compared to sleep and significantly higher for hunger compared to craving. Maximum likelihood classifiers achieved accuracies above 88% when differentiating between the three conditions.

Conclusions: High-frequency inter- and intra-hemispheric PLV in the NAc is a promising biomarker for closed-loop DBS that differentiates LOC-associated cravings from physiologic states such as hunger and sleep. Future trials should assess PLV as a LOC biomarker across a larger cohort and a wider patient population transdiagnostically [1).

[1)
Rolle CE, Ng GY, Nho YH, Barbosa DAN, Shivacharan RS, Gold JI, Bassett DS, Halpern CH, Buch V. Accumbens connectivity during deep-brain stimulation differentiates loss of control from physiologic behavioral states. Brain Stimul. 2023 Sep 19:S1935-861X(23)01912-5. doi: 10.1016/j.brs.2023.09.010. Epub ahead of print. PMID: 37734587.