Neural oscillations, circular causality and the implications for nature

Tolga Esat Özkurt

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The actual causal nature of neural events may not be evaluated simply by rational thought alone but instead by empirical observation. Neuroscience community specifically interested in the measurements of noninvasive EEG-MEG (electro/magneto-encephalo-graphy) and invasive LFP (local field potential) data, has witnessed a common paradigm shift regarding the causal relations between micro level neuronal spike activity and macro level neural oscillatory activity.

From the very beginning of brain electrophysiology research, neural oscillations were considered to be mere epiphenomena; i.e., byproducts of hundreds of thousands of neurons and possessing no “active” functional roles but being only correlative markers. This view was well in line with the classical physicalist notion of the strictly one-directional bottom up causality relations presumably existent in nature. Accordingly, action potentials arising due to the chemical – electrical reactions occurring within and between the neurons lead to the postsynaptic potentials, which are the sources of neural oscillations, hence being simply passive reflections of micro level.

However, contrary to the traditional view, recent empirical studies suggest causal roles for neural oscillations. Weak electrical fields were shown to change animal brain network activity and function (e.g., Francis et al., 2003), even though the magnitude of these fields were deliberately kept not sufficient to produce action potentials as they made very little changes in somatic membrane potential of the individual neurons (Fröchlich and McCormick, 2010). Note that endogenous electrical fields are basically spatial gradients of LFPs, which have the oscillatory characteristic. There are also various electromagnetic stimulation studies applied on human brains noninvasively, where stimulation at some specific frequency induces cortical oscillations and cause cognitive effects intrinsic to the band. For example, 10 Hz tACS (transcranial alternating current stimulation) can synchronize brain rhythms within the range of alpha band, at the parieto-occipital regions and subsequently modulate visual perception performance (Helfrich et al., 2014). Note that the alpha band activity at those brain regions are already intrinsically related to that particular cognitive task performance regardless of any external stimulation.

Overall, micro-neuronal fluctuations cause macro-neural oscillations, which in turn cause those very micro-neuronal activities. Hence, the new paradigm, evidenced by various empirical brain studies, changes the one-directional causality concept into a circular one. I should also note that LFPs have been observed in diverse scales: from tens of neurons to millions of them. Furthermore, the large scale oscillatory sources composing EEG-MEG data connect with each other via phase and amplitude connectivity measures. Hence, circular – multidirectional causal loops may exist hierarchically through out the whole brain.

It is arguable whether the ontological implications of these observations would suggest a major revision of our understanding of causation *per se*. Circularity of causes makes one question the validity of fundamental bottom-up one directional reductionist causality

paradigm, which prohibits any top-down relation in whole reality. The causal relations at different levels, such as particles, atoms, molecules, cells, tissues, brains and organisms may not also be one-directional, at all.

References:

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