Editorial

Entrainment and coherence in biology

INTRODUCTION

Coherence and chaos walk hand in hand in biological systems. Any living system is a complex entity interacting with the environment in many predictable and some unpredictable ways. Unpredictability stems from the fact that we are not able to understand the workings of the system. Thus, there is a need for mathematical and physical models for many functions of the body. For example, seemingly unrelated and chaotic behavior is considered "normal" in the function of neurons of the brain. Any coherent and correlated discharge of the neurons of the brain is considered unusual indicating need for close monitoring and possible intervention. However, for normal functioning of cardiac muscles, coordinated and systematic discharge of the neurons is necessary. Thus, in different parts of the biological system, different types of activities of the neurons are considered "normal."

ENTRAINMENT

Entrainment is a process through which independent systems interact with each other. When two signals are close to each other in frequency, they fall into a single frequency.[1] The "entraining" signal could be from inside the body or from outside. For example, an external signal, optical or acoustic, derived from electroencephalogram could drive the brain rhythms (such as α waves) to optimum values. One of the most common entraining signal sources is the so-called Schumann resonance (SR). This resonance occurs as electromagnetic waves bouncing back and forth between the surface of the earth and the ionosphere. Ionosphere contains full of charged particles and behaves like a mirror for low-frequency electromagnetic waves. SR is the result of these oscillations, and the resonance frequency falls within the α range of the brain waves. It is thought that this resonance is essential for normal human activity; it is possible that entrainment of biological signals between humans could be understood on the basis of SR.[2]

Further, chanting certain mantras seems to entrain some physiological functions in the body. "It was observed that during both prayers and mantras, there was an increase in the synchronicity of cardiovascular rhythms when they were recited 6 times a minute. There was also an increase in baroreflex sensitivity."[3] Since most tissues in the body are piezoelectric, it is possible to explain that chanting could elicit electrical activity that could drive other physiological signals into entrainment.

Another example of entrainment is through thinking alone. Heart rate normally varies in a random fashion; heart rate variability (HRV) has come under intense study to determine cardiac response during stress. It is possible to observe sympathetic and parasympathetic activities when we record HRV and its time and frequency domain transforms. Entrainment of HRV and respiratory rhythm is reported during "pleasant and loving thoughts."[4] The above two examples illustrate ways through which we could intentionally entrain two signals in the body; the physiological advantage of this type of entrainment is not clear yet. It is likely this could be used for management of some abnormal rhythms of the body.

COHERENCE AND SYNCHRONY

Coherence is a measure of how close in phase two signals are to each other. If two signals increase and decrease in amplitude in exact phase, then the signals are said to be fully coherent. Any small perturbation and a minute change in temperature will destroy coherence. In a biological system, such coherences are rare. Froehlich in England had suggested that the body makes use of long range coherences for possible energy conservation and control.[5] This well-received concept is not taken up for discussion in this paper.

It should be noted that synchrony is not necessarily coherence. Normally many events are taking place in the body – such as respiration, cardiac activity, and stomach motility – that are thought to be independent of each other. These events are not coherent in the strict mathematical sense. However, some neural discharges may follow a time sequence! Example of sequential action is seen in cardiac activity; the sino-atrial node initiates neural discharges that travel down the conducting fibers of the heart so that cardiac muscles are activated in a time sequence. First, the atria are activated, followed by ventricular depolarization thus letting blood be pumped from atria to ventricles and then to the systemic circulation. Here, a sequence is required. All neurons cannot and should not depolarize at the same time in which case all cardiac muscles will contract at the same time without leaving

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time for filling and then pumping the contents. This could lead to fibrillation, the heart pulsating without pumping, and this needs immediate action such as defibrillation of the heart.

Brain is a more complex system; there could be both chaos and coherence! Let us look into chaos and resulting "normal" functioning of the brain. There are billions of neurons in the brain with complex interconnections, glial cells and inter-neurons that give brain capacity to learn, imitate (through mirror neurons), and consolidate memory. Buddhi, manas, citta and ahamkhara are all related to the activity of the brain. Normally, the neurons in the brain are acting independently, firing randomly. This randomness (internal memory consolidation and self-oscillatory circuits) keeps the brain in a normal mode without large coordinated outputs. If for some reason, the random firing of neurons becomes organized. Then it could result in consorted discharges with the possible epileptic-like activity resulting in sensory motor outbursts. Hence normally, coordinated and coherent activity of the brain neurons is of clinical interest.

This, fortunately, is not true of every coherent activity of neurons in the brain. Exceptions are in some yoga related procedures such as in dharana and dhyana. In a review paper, the authors have summarized observations in mindfulness and transcendental meditations wherein cardiac and respiratory synchronization is reported which is not seen during normal relaxation.[6] The paper proposes "a mechanism of neurophysiological changes during meditation at the cellular level based on neurovascular coupling, and at the global brain activity level from the autonomic response generated by cardio-respiratory synchronization" (p. 3).[6]

It is further postulated that higher coherence between different sites of the brain may be associated with higher creativity, emotional stability and overall improvement in moral and ethical attitudes.[7] Since higher coherence between two areas of the brain implies these areas are interlinked in activity, such coherence may produce a global effect and could lead one toward higher states of consciousness. In other studies also, it has been observed that executives who had undergone yoga training had better coherence of brain waves than controls.[8]

CONCLUSION

Research in meditation has opened doors of our perception to some unusual events taking place in the brain. The consequences of brain coherence reported are difficult to understand fully at this time. It could be involved in improving memory, regulate emotional responses, reduce effects of stress and useful in the management of some geriatric problems.

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