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Commentary

Heartbeat, Brain Oscillations and Body Awareness: A Commentary

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New empirical findings regarding the impact of pressure pulsatility on brain functions allow for a completely new interpretation of the coupling between brain and body oscillations. It has been found that during alert wakefulness, heart rate is frequency coupled with brain oscillations enabling body awareness. During sleep, frequency coupling between the heart and brain disappears leading to a loss of body awareness.

In his interesting and insightful review, Hamill [1] convincingly showed that mechanosensitive pyramidal neurons respond directly to heartbeat- and breathing-induced pressure pulsatility. Thus, besides a (i) neuronal, (ii) biochemical (transmitter and neurohormonal), an (iii) electromagnetic field (ephaptic coupling) pathway (see e.g., [2]), a fourth communication pathway exists that may be termed, "pulsatility sensitive pathway", which allows for a completely new interpretation of brain functions.

In this commentary, I wish to draw attention to the hypothesis that heartbeat might be considered a sort of "pacemaker" for brain oscillations, but only during alert wakefulness. This hypothesis rests on two different sources of evidence: Empirical findings documenting a pulsatility sensitive pathway and theoretical evidence that is summarized by the binary hierarchy brain-body oscillation theory [3,4]. This theory is based on the fact that phase coupling between two brain oscillations plays an important role for the communication between different neural networks (e.g., [5]), but depends on frequencies ($f_{(1)}$, $f_{(2)}$) with a frequency relationship r that equals an integer ($r = f_{(2)}/f_{(1)}$) = integer; $f_{(2)} > f_{(1)}$). Thus, if different frequencies are spaced as closely as possible, r = 2 for any frequency relative to its closest slower integer neighbor. In this way, a binary hierarchy of frequencies emerges, where any frequency $f_{(i)}$ equals $f_{(i)} = 2^i$ (i is any integer that refers to the rank in the hierarchy). The interesting point is that the frequencies of brain and body oscillations can be predicted, if we introduce a scaling factor s: $f_{(i)} = s \times 2^i$, and if we consider the traditional electroencephalogram (EEG) center frequencies for delta, theta, alpha beta and gamma, which are around 2.5, 5, 10, 20 and 40 Hz respectively. If we substitute any of these center frequencies by considering their rank in the hierarchy which is i = 1, 2, 3, 4 and 5 for delta, theta, alpha, beta and gamma respectively, we obtain 1.25 Hz for s. As an example, for alpha with a center frequency of 10 Hz and a rank of i = 3 we obtain: $f_{(3)} = s \times 2^3$, s = 10/8 = 1.25 Hz. The important conclusion is that $f_{(0)} = s \times 2^0$ = 1.25 Hz represents heart rate (HR) with 75 beats per minute. Thus, according to the binary hierarchy theory, $f_{(0)}$ = HR is the basic frequency and scaling factor of brain and body oscillations, as Hamill [1] correctly states.

Considering the impact of the pulsatility sensitive pathway on the neural activity of the brain and the implications of the binary hierarchy theory, the conclusion is that HR can easily induce phase locking with brain oscillations, enabling communication between different neural networks and the heart. Therefore, the heart beat may also be considered a "pacemaker" for brain oscillations. But what is the functional meaning of this heart-brain coupling? Based on the following finding, the most likely answer is that this coupling represents (or enables) body awareness: When brain oscillations, HR and breathing frequencies (BF) are recorded during an awake state and during sleep, the binary hierarchy between brain and body oscillations brakes apart in sleep: HR no longer functions as scaling factor for brain oscillations [6], but HR and BF are still binary coupled! Because there is no reason to assume that the pulsatility sensitive pathway is not operating during sleep, the question is why is it that in sleep the heart fails to synchronize brain oscillations. The reason is that the frequency relationship between brain oscillations (in this case spindle frequency) shifts towards a frequency relationship that includes the golden mean g (g = 1.618…), which is the most irrational number, known to separate different frequencies, not allowing them to phase lock [7].

Thus, when considering the implications of the pulsatility sensitive pathway and the binary hierarchy theory, the conclusion is that body awareness is established by mechanosensitive pyramidal neurons in the brain that oscillate with a frequency that is induced by HR and which has the potency to transiently phase synchronize with the traditional EEG center frequencies. During sleep, however, this frequency relationship and body awareness is lost.

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Conflict of Interest

The author declares no conflict of interest.

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