Biology, Brain Rhythms, and Consciousness

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Late in the previous century, there seemed to be good reasons to think that the physical make-up of a system could not matter much to whether that system had a mind. The *organization* of the system is what matters, people thought, and physically different systems can be organized the same way. As a result, artificial minds making use of ordinary computer hardware should be possible.[1] This whole discussion was hypothetical, because there weren't any convincing possible cases of artificial minds to worry about.

Since then, two things have happened. From around 2022, we've been confronted with candidates for artificial minds that are disturbingly impressive. These are the LLM systems, such as ChatGPT. But reasons have emerged to doubt that the physical make-up of a system is irrelevant and minds are "substrate independent." A view sometimes called biological naturalism holds that the biological details of nervous systems might make a difference to whether a physical system has a mind.[2] (The term was coined, with this sense at least, by John Searle.)[3] But if nervous systems and brains are special, what is it that makes them special?

This question can be asked for different aspects of mentality. Perhaps an artificial system using computer hardware can be genuinely intelligent but without feeling

[1] https://philpapers.org/rec/PUTPP-2
[2] https://www.cambridge.org/core/journals/behavioral-and-brain-sciences/article/conscious-artificial-intelligence-and-biological-naturalism/C9912A5BE9D806012E3C8B3AF612E39A
[3] https://www.annualreviews.org/content/journals/10.1146/annurev.neuro.23.1.557

anything. Perhaps biology matters to feeling but not to intelligence. Alternatively, one might think that something like a living brain is needed for genuine intelligence (or intelligence beyond a very low level), and much of the apparent intelligence in today's AIs is illusory.[4]

Here I will look mostly at the first option, the idea that the make-up of nervous systems is important to felt experience and less important to intelligence and cognition. These two sides can't be completely separate, but perhaps the difference that a nervous system makes to the cognitive side of the mind is rather fine-grained, whereas it makes a big difference to the possibility of felt experience or consciousness.

Biological naturalism is not the idea that two systems that *do exactly the same things,* internally and externally, but have different physical make-ups, can differ in whether they are conscious. The claim is that what a system *does*, its organization and processing, is dependent on its physical make-up in ways that matter to having a mind. A brain has different activities going on inside it than a computer does, however the computer is programmed. The rival view is that the differences between a living system and a computer are real, but don't matter.

A brain is made up of living cells, bounded by membranes, consuming glucose, interacting through tiny releases of chemicals, fed from a blood supply, and so on. Which of the details of how the brain does things might be important to consciousness? I'll look at one view in this area, a hypothesis I see as likely to contain at least some truth.

Among all the activity going on in a brain, we can distinguish two kinds. First, neurons "fire" or "spike" (a sudden electrical fit in that cell), and encourage or discourage the firing of others by sending puffs of chemicals across the gaps between them. These activities form a network, where one individual cell affects others. No one denies these activities are immensely important to what a brain does. These are also the activities of a brain that can most readily be "transported" to a computer—not just represented, but also given a kind of physical reality in the computer's hardware.

Second, a brain also has within it a collection of slower, more diffuse electrical processes, such as rhythmic oscillations that span large parts of the brain. Physically, these involve rhythmic movements of charged particles (ions), to and fro, across the membranes of cells. These rhythms were uncovered in the late nineteenth and early

[4] https://iai.tv/articles/water-not-silicon-has-to-be-the-basis-of-true-ai-auid-3200

twentieth centuries, especially by Hans Berger.[5] They can be measured from outside the skull using an EEG device.

Are these oscillations just a lot of those cell-to-cell network interactions, seen from a zoomed-out point of view? No: although the physical basis of the rhythms is controversial, there's more to them than that. The electrical rhythms affect the "spiking" of neurons, and the spikes affect the rhythms, but they are partly distinct.
Why might they matter, especially to consciousness? This part of neuroscience is full of controversies and uncertainty—I want to emphasize that. But let's cautiously work our way forward.

There are clearly associations—of some kind—between various brain rhythms and what I'll call *consciousness-related* properties. Different rhythms are seen during sleep and wakefulness, also in anesthesia.[6] While awake, different rhythms are seen when a person is relaxed, or focused and attentive. That does not mean much on its own. A lot of neuroscientists think that the rhythms are mere byproducts of more important activities. Because of the nature of cells and the activities within them, perhaps neurons will naturally oscillate even though this has little effect. Physical oscillators also tend to get synchronized with each other (an interesting fact, but not one tied to the mind, as pendulum clocks do it too).[7] This will give rise to large-scale rhythms. And perhaps these rhythms will speed up or slow down according to different versions of the "more important activities" going on.

This is a view in which brain rhythms are no more important than the hum of an (older!) computer. Another view is that the rhythmic patterns do have some role, but they are part of the general management of activity—keeping things from getting out of control in various ways. They don't contribute to what someone is thinking or feeling, though they do help the machine run. This "supporting" activity could vary across different states the brain is in.

How could we show that the oscillations do more than that? It's not easy. In the late twentieth century, some neuroscientists including Rodolfo Llinás, Wolf Singer, and others argued that a specific kind of fast oscillation, in the "gamma" range, is important

[5]https://journals.lww.com/clinicalneurophys/citation/1993/10000/history_and_evolution_of_electroencephalographic.7.aspx
[6] https://www.cell.com/cell-reports/fulltext/S2211-1247(25)00456-5?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS2211124725004565%3Fshowall%3Dtrue
[7] https://www.nature.com/articles/srep23580

in “binding together” features in our visual experience, such as colors and shapes of objects. (Francis Crick, of DNA fame, also defended this view.)[8] This most famous possible link between oscillations and consciousness remains very controversial. The general principle introduced by this hypothesis can be applied more broadly, though. Large-scale oscillations might provide an organizing and unifying platform for cell-to-cell interactions (and some more ambitiously suggest that they might also be a medium for representation).[9] Oscillations enable neurons to fire in a synchronized way across separated brain areas, for example. Some intriguing recent work shows that if a particular kind of slow oscillation is pushed into more synchrony with an electrical device applied to the scalp, people can do better at memory tasks.[10]

Here is another piece of the puzzle. Nervous system oscillations of this kind are all over the animal kingdom. Brain rhythms that are similar to ours are found in bees, flies and octopuses. In a simple form, they are even found in jellyfish-like animals (which have no brain, but do have a nervous system). This can be taken to support the view that oscillating is something that nervous systems just do, easily or inevitably, without playing much of a role. And how could oscillations have a role in consciousness if they are found in animals, like jellyfish, that are probably not conscious at all?

One of the surprises here, though, is that the associations between various oscillation patterns and what I called consciousness-*related* properties are also seen all over the animal kingdom. They, too, are seen in flies, bees, and octopuses. These animals have a wake-sleep distinction (several kinds of sleep, in fact), can be “put under” with anesthesia, and also show forms of attention.[11]

Consciousness-related features in insects are studied in Bruno van Swinderen’s laboratory at the University of Queensland.[12] Their work has shown, for example, that bees and flies can attend to particular objects when more than one is visible. Attention, as detected in the brain, precedes a choice of where to move. And attention in flies has a close association with brain oscillations in the “beta” range, a range that is also important in humans. In one experiment, Martyna Grabowska and her collaborators showed not just that a fly’s direction of attention can be worked out by looking at beta

[8] https://linkinghub.elsevier.com/retrieve/pii/S1364661399012991
[9] https://ekmillerlab.mit.edu/earl-miller/
[10] https://www.neuromodulationjournal.org/article/S1094-7159(23)00009-0/fulltext
[11] https://www.nature.com/articles/s41467-017-02024-y
https://onlinelibrary.wiley.com/doi/10.1002/neu.20300
https://www.sciencedirect.com/science/chapter/edited-volume/abs/pii/B9780444529770500036
[12] https://qbi.uq.edu.au/profile/250/bruno-van-swinderen

oscillations, but that the fly's attention can be switched to an object that would normally be less interesting to it by using a reward circuit in its brain, and this was also visible in a change to the beta oscillations.[13] This is less convincing than showing that some ability in the fly, or its attention, can be directly affected by manipulating the oscillations themselves (as in the memory studies in humans I mentioned), but it's pretty remarkable. The association, at least, between oscillations and consciousness-related features is looking pretty tight.

If these oscillations are important, why couldn't they be programmed into an AI system along with all the rest? They can certainly be *modeled* with a computer program—a computer might go through calculations that represented oscillations of various kinds. But that is not the same as having these rhythms as part of the machine itself. In a brain, tiny charged particles flow back and forth across billions of cell membranes, in a coordinated way, interacting with the firing of cells in the network. Perhaps something like this could be introduced into an artificial brain-like system in the future, but it would take a different kind of hardware from anything around (as far as I know) now. This would be an artificial hardware in which the sizes and shapes of different parts of the system affected how the internal rhythms were maintained. Something resembling cell membranes would need to be present in the "nodes" of the signaling network. This system might not be fully alive, but it would be more like a living brain than a present-day computer is.

I'll raise one other possibility, a more speculative one, about how large-scale rhythms might be relevant to consciousness. This one is not based in experiments, but draws on our everyday life.

First, here's an overall picture of brain functioning that's supported by the kind of work I've been describing. A brain is full of spontaneous activity, including large-scale rhythms coming and going in different forms. When we see or hear things, those stimuli modulate the brain's activity, and many things can modulate the activity at once. Now ask: what is ordinary experience like? How do things feel right now? Scientists sometimes claim that only one thing can be in conscious awareness at once.[14] I find this hard to believe, I must say, and if you are at all like me, experience at each moment is multifaceted. A lot of things contribute to "what it's like to be you" at this moment. Something might be in the center of your attention, but there are also your mood, energy level, ambient sounds, how your body feels, and more. All this can be called an

[13] https://pnas.org/doi/full/10.1073/pnas.2010749117

[14] Dehaene, *Consciousness and the Brain.*

experiential profile. If we think of brain activity the way I suggested a moment ago—with large-scale patterns being modulated by various things at once—doesn't it seem that brain activity has the right *shape* as a potential explainer of felt experience—of what it's like to be you?

I've focused here on large-scale oscillations in the brain, both because of the intriguing experimental work and because of the general picture of brain activity that they suggest. These aren't the only biological features of nervous systems that might have a role in consciousness while being resistant to being brought into a computer; another one might be the goal-directedness of individual cells. "Biological naturalism" can take different forms according to what it is in the biology that's seen as important. Electrical oscillations might be just one such factor, but I think they are part of the story.[15]

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[15] Thanks to Alasdair Craig of IAI News for some very good ideas during the editing process.