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Comment

Wanted: Architecture for changing minds
A comment on "The growth of cognition: Free energy minimization and the embryogenesis of cortical computation"

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1. Use it, in sync, or lose it

The discussion of what makes a neuron survive or instead be sacrificed by apoptosis is an excellent opportunity to remind oneself that the cortex is a network. A community were the fate of the individual is determined by the collective. This is demonstrated most convincingly in Wright and Bourke's treatment of the role of neural synchrony during cortical embryogenesis, as well as by their impressive growth simulations [4]. While doing so, they provide a bridge between Friston's powerful Free Energy principle [1] and Perlovsky's elegant Dynamic Logic framework [3], and complement them both in encouraging ways.

The proposal that the survival of neurons is promoted by their synchronized activity with other, sometimes distant, neurons fits well with previous data, as reviewed. Moreover, it can help explain long-standing conundrums, such as why the innate columnar selectivity in visual primary cortex still requires actual experience for maintaining that organized selectivity [4]. It is further proposed that this synchrony is spatially partitioned and transcends small-world assemblies, as well as that this model is applied in all cortical areas.

Naturally, what dictates the brain's architecture and how it evolves to suit its many functions is a monumental topic of prolonged scientific interest. In discussing the architecture, however, it is often apparent that we implicitly consider the brain as an organ that copes with varied circumstances with the same, fixed machinery. But as will be argued below, the human brain is able to accommodate diverse contexts, which can be radically different, by changing states of mind dynamically. Therefore, an important step towards our understanding of the underlying architecture, extending from the work of Wright and Bourke's, is thinking how the same architecture can subserve different states.

States of mind, as we have recently defined them [2], can vary along multiple dimensions. Here are a few examples. Perception can be based on bottom-up information from the senses, or lean more on top-down expectations that are based on experience as stored in memory. When attending a physical scene, we may be focused on the local details (i.e., the "trees") or on the global information in that scene (i.e., the "forest"). We can be thinking in a broad and associative manner, or we may be focused with our thoughts narrowly on the same topic for an extended amount of time, perhaps even ruminating in more clinical cases. Our mood can be more positive or more negative. And when it

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comes to our openness to experience and tolerance for uncertainty, we can be more exploratory (attracted to novelty, learning and curiosity) or more exploitatory (gravitating toward the safe and the familiar).

These are all continuums: one can be more or less from each, sliding dynamically from one end to the other depending on circumstances. For example, one can be leaning more on memory and past experience when in a familiar environment, more dependent on sensory information when facing a novel situation, or anywhere in between these extremes. Importantly, we have noticed that all those dimensions—perception, attention, thought, mood and openness—change in tandem, and as a result proposed that they form an overarching state of mind (SoM). When one is perceiving more based on bottom-up sensory information rather than memory, she also attends the world more globally, thinks more associatively and is more exploratory. Each such SoM is accompanied by specific tendencies and dispositions, which always come together as a cluster. In other words, our mind is different in different contexts.

2. Same brain, different states

When you first learn about bi-polar disorder, you can't help wondering how could the two very different minds, depressed and manic, exist in the same brain. While typical SoM variations are less extreme, we still do not have a good account for how the same brain, the same architecture, could give rise to a mind that is sometimes exploratory and sometimes exploitatory; sometimes broadly associative and sometimes ruminative. The actual architecture should have flexibility that current thinking does not fully embrace yet.

How could fixed weights and strengthened connections mediate dynamic states of mind? Our own proposal for what mediates differing states is that SoM is determined by the ratio between top-down and bottom-up processing [2]. Bias toward more top-down processing implies a narrow state of mind: local attention, perception by expectation, narrow thinking. Bias toward bottom-up information, on the other hand, implies a broad state of mind: exploratory, global and more positive. For a more complete account, we should understand next how neurotransmitters and neuromodulation help utilize the same architecture so differently to give rise to and support different states of mind, which make us mentally flexible and ultimately adaptive to the diverse contexts we encounter in our daily lives.

Taking it for granted that we seek to minimize surprise at all times, or that we aim for minimal free energy, is what has led to the thinking, at least implicitly, that we have one mind, and thus a fixed architecture should suffice. But this would be an exploitive mind, with little learning and little thrill.

Our next step, therefore, should be to think of the differences in patterns of synchrony, possibly small-world assemblies that change boundaries dynamically according to state, or any other activation mechanism that will use the same infrastructure to give rise to those frequent and qualitative changes in our SoM. We should not always strive to diminish degrees of freedom, or else we will never be able to explore.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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