An exciting path ahead

Comment on “Path integrals, particular kinds, and strange things” by Friston K, Da Costa L, Sakthivadivel DAR, Heins C, Pavliotis GA, Ramstead M, and Parr T

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ABSTRACT

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It is almost two decades ago that Karl Friston presented the core ideas of the Free Energy Principle (FEP) at the opening keynote lecture of the 2006 Human Brain Mapping meeting in Florence. The talk introduced to a community of neuroimaging researchers a novel, broad-scope theoretical perspective on neural function described in two papers that had just been published [1, 2]. I remember being equally intrigued and taken aback by the talk, a sentiment seemingly shared by the majority of the audience. While the FEP remained indeed somewhat under the radar of the scientific community for a while, it has recently become one of the more actively developed and exciting area of theoretical neuroscience (see Figure 1). Its scope has also crossed the boundaries of neuroscience, with researchers adopting it to try and understand self-organizing adaptive systems [3] in areas as diverse as cell biology [4], botany [5, 6], evolutionary biology and developmental dynamics [7], social behavior [8, 9], and ecology [10].

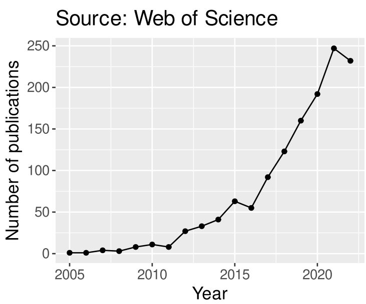

Figure 1: Number of scientific articles published in the years 2005–2022 with ‘free energy principle’ or ‘active inference’ in their keyword list.

The FEP was conceived as an original formulation of the processes underlying action and perception in living beings, unifying them as different manifestations of the same general mechanics of Bayesian beliefs. The main idea is that systems that are able to preserve their overall structure and dynamics can be seen as minimizing the probability of incurring into ‘surprising’ states, where surprise is defined with respect to a generative model of the world embodied by the organism. This can be done either by updating the organism’s beliefs or by generating actions that bring about the sensory data that the organism is expecting. Both of these strategies, in fact, minimize variational free energy, which is just a computationally-tractable upper bound to surprise. This framework was subsequently extended to account for the cognitive faculties of planning and decision-making, thereby conceiving also future sequences of actions (*policies*) as beliefs that need to be inferred by the agent on the basis of predicted sensory data. The inferential process underlying policy selection is thus guided by the minimization of not only variational free energy, but also of the *expected free energy* as a foreseen consequence of undertaking a given policy. Furthermore, the identification of a system as a distinct

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'thing' from the rest of the world was formalized by the notion of *Markov blanket*, a statistical membrane partitioning the state space into a sparse coupling structure between external, sensory, internal, and active states.

The article by Friston et al. [11] in this issue marks a novel step in the generalization of the FEP. Based on the principle of least (stationary) action, it recasts the FEP within a path integral formulation, where the path representing the behavior of a system is expressed as a point in generalized coordinates of motion (i.e., the time derivatives of the states of motion up to the *n*-order). This move produces a very elegant reformulation of the FEP, one that crucially can be applied uniformly to various kinds of systems or 'particles': inert particles (without active states), active particles (with active states), ordinary particles (whose active states can directly influence internal states), dissipative particles (subject to random fluctuations), conservative particles (with negligible random fluctuations), and finally 'strange' particles (whose active states are *hidden* from the internal states and have thus to be inferred). This latter 'particular kind' is especially interesting as it corresponds to the category of sentient beings, whose generative model must include Bayesian beliefs about the potential consequences of their own actions, and thus necessarily a temporally-extended sense of Self.

The current formulation also allows to accomodate some critiques raised by researchers working within the enactive approach to cognition and life [12]. In particular, it does not require the system under study to be in a non-equilibrium steady state, an assumption that was questioned noticing how biological organisms can undergo dramatic changes in both structure and function during their lifetime while preserving nonetheless their identity. Furthermore, the notion of representational knowledge — another point of strong contention — has here a much more 'deflationary' flavor: adaptive systems, behave 'as if' they use a model of their environmental niche, but in fact the 'representations' that make up the phenotype of such systems are really just probabilistic belief landscapes constraining the paths along which behavior and cognition unfold, with no need for a distinct 'central controller' (see also the brilliant metaphor of the dam in Hohwy [13], Chapter 3).

Finally — beyond the compelling intellectual appeal of seeing the same fundamental principle applying to physical, biological, and psychological phenomena — the formal characterization of the properties of 'strange things' like us provides a much needed mechanistic platform for the development of notoriously elusive areas of scientific investigation, such as subjective experience [14, 15], mental action [16, 17, 18, 19], psychiatric illnesses [20], and consciousness [21, 22]. Even though only the initial steps on the path have been traced, the 'particular' approach outlined in [11] has a great potential, in my opinion, for triggering a significant advance of our knowledge in these fields.

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