Available online at www.sciencedirect.com

ScienceDirect

Physics of Life Reviews ••• (••••) •••–•••

PHYSICS of LIFE reviews

www.elsevier.com/locate/plrev

Comment

Hierarchical Markov blankets and adaptive active inference Comment on "Answering Schrödinger's question: A free-energy formulation" by Maxwell James Désormeau Ramstead et al.

Michael Kirchhoff

Received 28 December 2017; accepted 28 December 2017

Communicated by J. Fontanari

Ramstead MJD, Badcock PB, Friston KJ. Answering Schrödinger's question: A free-energy formulation. Phys Life Rev 2018. https://doi.org/10.1016/j.plrev.2017.09.001 [this issue] motivate a multiscale characterisation of living systems in terms of hierarchically structured Markov blankets – a view of living systems as comprised of Markov blankets of Markov blankets [1–4]. It is effectively a treatment of what life is and how it is realised, cast in terms of how Markov blankets of living systems self-organise via active inference – a corollary of the free energy principle [5–7].

A Markov blanket defines the boundary of a system, and can thus be understood as a universal requirement for life [6,8]. Crucially, a Markov blanket is a statistical partitioning of a system into internal states and external, environment states [6]. Specifically, the blanket itself consists of the states that separate internal and external states; namely, active and sensory states [7]. Under the free energy principle, active inference, in its simplest formulation, describes the tendency of any random dynamical system to minimise (on average and over time) its variational free energy, where the free energy quantity functions as an upper bound on (negative) marginal likelihood or evidence. In the context of Markov blankets, this means that the active and sensory states comprising a Markov blanket can be understood to work to optimise evidence for the dynamics underlying the organisation of a (living) system. In their survey, Ramstead et al. propose that the very same statistical structure of a single Markov blanket (enveloping a cell, say) can be recapitulated at increasingly larger and larger scales of self-organisation, inducing a series of hierarchically nested systems such as the body of a single organism [1,2]. They claim that this multilayered view of Markov blankets of Markov blankets follows from the existence of a single Markov blanket, where this Markov blanket is mandated by the fact that its internal states can be distinguished from its external milieu [8, p. 8].

In my opinion the thesis that the organisation of living systems consists of nested Markov blankets should be viewed as reasonably uncontroversial, even if non-trivially significant. Yet there is nevertheless an apparent complication with Ramstead et al.'s preferred account. The problem is that the Markov blanket formulation of life is overbroad in its explanatory scope. Indeed, Ramstead et al. mention that one can think of the surface of a cell or the skin membrane of an individual as a Markov blanket. But they also think it possible to cast particular nodes of the World Wide Web as possessing a Markov blanket. The scope of this formulation is likely to be too encompassing. If the Markov blanket formulation can apply to living things as well as non-living things (I assume that the internet or a pair of Huygens pendulums [6] are uncontroversially non-living), their proposal is open to being explanatorily vacuous. In other words,

DOI of original article: https://doi.org/10.1016/j.plrev.2017.09.001.
E-mail address: kirchhof@uow.edu.au.

https://doi.org/10.1016/j.plrev.2017.12.009

Please cite this article in press as: Kirchhoff M. Hierarchical Markov blankets and adaptive active inference. Phys Life Rev (2018), https://doi.org/10.1016/j.plrev.2017.12.009

the larger the scope of their preferred Markov blanket formulation, the less likely it is to say much about the specifics of *living* organisation [8]. In my opinion, the following distinction is underemphasised in their account: the difference between 'mere active inference' and 'adaptive active inference' [3]. The remainder of this commentary will speak to this distinction and address how it might augment Ramstead et al.'s view of how life is realised and how it is maintained.

The main difference between 'mere active inference' and 'adaptive active inference' turns on the ability to sample over different actions, which, in turn, is based upon temporally – and therefore spatially – deep generative models that minimise the free energy expected under different (counterfactual) courses of action. A Markov blanketed system that exhibits only mere active inference cannot sample over counterfactual outcomes of its own actions. But, this ability is arguably an essential feature of the organisation of life – at least of life as we know it. This implies that not all Markov blanketed systems that engage in active inference are living. Friston [6] associates a pair of Huygens pendulums with having a Markov blanket (the motion of the beam from which the pendulums are suspended). A pair of pendulums however cannot modulate their relation to the world, and therefore cannot be said to be able to adapt to a set of changing circumstances. The reason is that the dynamics of Huygens pendulums take the form of a Markov chain over (successive) time. A Markov chain captures the idea that events are conditionally independent of previous or past events given the current state of the system [9]. Markov chained systems are thus 'enslaved' by the dynamics of the here-and-now, viz., they do not exhibit adaptivity. Living systems are adaptive. Any adaptive system are not merely enslaved to their proximate conditions. This means that adaptive active inference is what enables living systems to make inferences about certain probabilistic future states and act to as to reduce the expected uncertainty associated with those future states [3,10].

The role of adaptive active inference in self-organising and maintaining the organisation of living systems highlight why it is not enough that the same statistical form of a single Markov blanket can be generalised recursively at larger and larger scales of systemic organisation when accounting for the hierarchical (Markov blanketed) organisation of life. This means that what is important is that the kind of active inference that underlies the self-organisation of hierarchical Markov blankets is associated with adaptive, future (and backward) oriented dynamics. Adaptive active inference not only speaks to the species of dynamics required for something to be and remain alive, it also provides a means by which to appropriately restrict the explanatory scope of one's account of life and its organisation.

Acknowledgements

Kirchhoff's work was supported by an Australian Research Council Discovery Project "Minds in Skilled Performance" (DP170102987) and by a John Templeton Foundation Academic Cross-Training Fellowship (ID#60708). The opinions expressed in this publication are those of the author and do not necessarily reflect the views of the John Templeton Foundation.

References

[1] Allen M, Friston KJ. From cognitivism to autopoiesis: towards a computational framework for the embodied mind. Synthese 2016:1–24. https://doi.org/10.1007/s11229-016-1288-5.
[2] Clark A. How to knit your own Markov blanket. In: Metzinger T, Wiese W, editors. Philosophy and predictive processing. Frankfurt am Main: MIND Group; 2017.
[3] Kirchhoff MD, Parr T, Palacios E, Friston K, Kiverstein J. The Markov blankets of life: autonomy, active inference and the free energy principle. J R Soc Interface 2018:20170792. https://doi.org/10.1098/rsif.2017.0792 [in press].
[4] Palacios E, Razi A, Parr T, Kirchhoff MD, Friston K. Biological self-organisation and Markov blankets. BioRxiv. https://doi.org/10.1101/227181.
[5] Friston KJ. The free-energy principle: A unified brain theory?. Nat Rev Neurosci 2010;11(2):127–38.
[6] Friston K. Life as we know it. J R Soc Interface 2013;10(86):20130475. https://doi.org/10.1098/rsif.2013.0475.
[7] Friston KJ, Levin M, Sengupta B, Pezzulo G. Knowing one's place: a free energy approach to pattern regulation. J R Soc Interface 2015;12:20141383. https://doi.org/10.1098/rsif.2014.1383.
[8] Kirchhoff M, Froese T. Where there is life there is mind. Entropy 2017;16:1–18. https://doi.org/10.3390/e19040169.
[9] Pearl J. Probabilistic reasoning in intelligent systems: networks of plausible inference. San Francisco: Morgan Kaufmann Publishers; 1988.
[10] Di Paolo E. Extended life. Topoi 2009;28:9–21.

Please cite this article in press as: Kirchhoff M. Hierarchical Markov blankets and adaptive active inference. Phys Life Rev (2018), https://doi.org/10.1016/j.plrev.2017.12.009