Thinking through prior bodies: autonomic uncertainty and interoceptive self-inference

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Abstract:

The Bayesian Brain Hypothesis, as formalized by the Free Energy Principal, is ascendant in the cognitive sciences. But how does the Bayesian Brain obtain prior beliefs? Veissière and colleagues argue that sociocultural interaction is one important source. We offer a complementary model in which “interoceptive self-inference” guides the estimation of expected uncertainty both in ourselves and in our social conspecifics.

Invited BBS Commentary on: Veissière, S. P. L., Constant, A., Ramstead, M. J. D., Friston, K. J., & Kirmayer, L. J. (2019). *Thinking Through Other Minds: A Variational Approach to Cognition and Culture. Behavioral and Brain Sciences*, 1–97.

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In their impressive synthesis, Veissière and colleagues argue that enactive social interaction is a prime ground for generating higher-order prior beliefs (both implicit and explicit). We share this enthusiasm for social-cultural patterning of priors, and also their comprehensive embrasure of the enactive and embodied turn within the larger predictive processing movement (Allen & Friston, 2018; Barrett & Simmons, 2015; Gallagher & Allen, 2018; M. J. D. Ramstead, Kirchhoff, Constant, & Friston, 2019; M. J. Ramstead, Kirchhoff, & Friston, 2019; Seth, 2013). As they elegantly argue, ontogenetic development provides a wealth of knowledge about how to behave in a given context. It follows that this ‘duet for one’ of mutual prediction not only constrains how we engage with others, but also our own self-inference (K. Friston & Frith, 2015; K. J. Friston & Frith, 2015). As such the proposal that much of our “repertoire of prior beliefs” emerges from socio-cultural interaction and enactive, embodied engagement is both feasible and exciting.

However, we disagree that “information from and about other people’s expectations constitutes the primary domain” from which prior beliefs about “statistical regularities” (i.e., expected precision) arise. While socio-cultural sources certainly contribute, we highlight the predominance of more than 1 million years of phylogenetic evolution in shaping our “prior bodies” as the key constitutive factor molding how we predict ourselves and other agents (Allen & Tsakiris, 2019). In advance of any ontogenetic development, one is born with homeostatic and morphological features which shape the expected statistics of one’s life, and these in turn provide a rich generative model which can be inverted to understand a wide range of human social behaviors.

Developing this view, we recently proposed a computational model of interoceptive self-inference (Allen, Levy, Parr, & Friston, 2019). Our model argues that the visceral body provides a fundamental

constraint on belief precision, and that interoception serves to sample these rhythms so as to better estimate expected uncertainty. This model formalizes other more conceptual accounts of interoceptive inference in the domain of emotion (Barrett & Simmons, 2015; Chanes & Barrett, 2016; Seth, 2013; Seth & Tsakiris, 2018), selfhood (Ainley, Apps, Fotopoulou, & Tsakiris, 2016; Apps & Tsakiris, 2014; Limanowski & Blankenburg, 2013), and metacognition (Petzschner, Weber, Gard, & Stephan, 2017). Our model generalizes beyond these to argue that the primary homeostatic rhythms of the body fundamentally constrain prior beliefs about the precision, or confidence, of both interoceptive and exteroceptive belief updates. This to say, visceral rhythms embed primary control dynamics, or hyper-priors, on the agent's landscape of precision. This in turn dictates the confidence I assign to any shift in my posterior beliefs and provides a useful starting point for estimating self-precision in others.

Figure 1. Interoceptive Self-Inference Model. A) Hierarchical precision-weighted inferences integrate confidence signals from the internal and external environment into an overall estimate of expected uncertainty. B) For example, slow respiratory oscillations stabilize cardiac cycles, resulting in low autonomic uncertainty. In contrast, a volatile breath pattern increases baseline neural uncertainty, as illustrated in a simulated brain response to a steady state exteroceptive input. C) These fluctuations can be modeled, e.g., by dynamic reinforcement learning approach in which the volatility of interoceptive state transitions inflates the estimate of autonomic uncertainty. Through inversion of the self-inference model to conspecifics, agents can predict the confidence of others' beliefs.

To illustrate the core of our model (summarized in Figure 1), consider the following example of sensory attenuation in the retina. In the eye, the pulsation of blood across the optic disk at each heartbeat distorts the retinal surface, briefly occluding ascending sensory information. In a hierarchical brain, this predictable fluctuation of precision is a crucial learning signal, which can be sampled via interoception to improve estimates of expected uncertainty (Parr & Friston, 2017; Pulcu & Browning, 2019). Expected uncertainty in turn provides an invaluable control signal dictating how much I should update my beliefs in the face of new information; Bayesian decision theory tells us that when confronted with a volatile environment (or a volatile colleague), one should more rapidly update their beliefs in response to prediction error.

Through simulation, we show that this simple coupling of sensory precision to the rhythm of homeostasis enforces a primary interaction between the body and our perception of the world. On our model, lesioning afferent viscerosensory information caused a cascade of interoceptive prediction error which elicit psychosomatic hallucinations, blunted belief updating, and attenuated physiological reactions. These domain-general alterations in precision ultimately cause agents to update their higher-order beliefs, resulting in top-down metacognitive biases (i.e., mis-estimation of expected uncertainty) that characterize many psychiatric and psycho-social illnesses (Lawson, Mathys, & Rees, 2017; Powers,

Mathys, & Corlett, 2017). In the inverse, maladaptive prior beliefs about self-uncertainty can elicit misperception or hyper-arousal in the interoceptive domain. This equips the model with a deeply circular, enactive causation; my expectation of confidence in the world constrains my visceral inference and regulation, and the statistics of visceral rhythms constrain my exteroceptive percepts and beliefs.

Here perhaps is where there is the most potential for crosstalk between the model of Veissière and colleagues and interoceptive-self inference. Our model suggests that agents are imbued at birth with a repertoire of “embodied priors” or statistical regularities dictated by their morphological forms, which act as hyper-parameters on meta-cognition and learning (Allen & Tsakiris, 2019). In particular, these priors influence the confidence or precision dictating the perceptual and emotional salience we assign to various interoceptive and exteroceptive outcomes. The notion of *Variational Niche Construction* developed by Veissière and others can be cast as building ontogenetic refinement on top of these fundamental constraints (Bruineberg, Kiverstein, & Rietveld, 2018; Bruineberg, Rietveld, Parr, van Maanen, & Friston, 2018). That is to say; in thinking through other minds we demarcate novel boundaries of salience, refining the embodied set-points that define a landscape of precision for agents. We maintain however the hegemony of the phylogenetic body in setting these starting points; ultimately, the strongest possible source one can sample from concerning the volatility of others is found within oneself.

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