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Not Only in or of the Observer: A Neuroscientific View on Uncertainty

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> Abstract • While Druzhinin and Ramírez locate uncertainty in the reflective consciousness of the observer, from a neuroscientific perspective, it is understood as an intrinsic property of the inferential architecture of the brain. As such, uncertainty is not (only) experienced, but computed and regulated within predictive processing systems. It forms the basis for learning and adaptation and is the driving force behind conclusions, active exploration, and understanding.

Handling Editor • Alexander Riegler

« 1 » While uncertainty as a subjective and reflective state can only be attributed to persons, computational and information-theoretic approaches in neuroscience assume that the brain can also represent or encode uncertainty in a computational sense. In Bayesian brain theory (Knill & Pouget 2004), uncertainty characterizes the variance of probabilistic beliefs and sensory evidence (Vilares & Kording 2011), whereas precision refers to its inverse, i.e., the confidence assigned to predictions and prediction errors (Yon & Frith 2021). In this sense, referring to uncertainty in the brain is a convenient shorthand for a formally definable property of inferential processes: the brain constantly encounters uncertainty and resolves it, with or without our conscious insight, as part of its computational architecture.

« 2 » Neuroscientific research in recent decades has transformed the brain from a black box limited to stimulus–response mappings into a "predictive machine." Through comprehensively trained and constantly optimized internal models, it does not merely faithfully record the sensory world, but actively constructs it (Bubic, von Cramon & Schubotz 2010; Clark 2013; Schubotz 2015). Since it has no direct access to its environment but relies on the excitation patterns of sensory receptors, the brain is constructing internal generative models to uncover the hidden (latent) causes of sensory inputs (Friston 2005). An unpredicted stimulus results from the divergence between the currently predicted and the experienced sensory stimulus, which is referred to as "prediction error." If this error is large enough, it becomes a teaching signal that prompts the internal generative model to be adjusted or changed (Gershman et al. 2017).

« 3 » In contrast to the Bayesian brain account, predictive coding is a process model that specifies how the brain continuously minimizes uncertainty through inference and learning. Uncertainty is thus reduced in two ways: by updating the predictive model to fit the sensory stimuli (through perceptual inference) or by acting on one's environment to fit the model (through active inference). In both cases, the prediction error is minimized (or mutual information – in the Shannon-theoretic sense – maximized, Little & Sommer 2013) in order to maintain adaptive coherence between expectation and experience.

« 4 » For the organism, it is not the ontological status of that which is modeled – i.e., a presumably mind-independent world – that is relevant, but rather the functional adequacy of these processes for maintaining adaptive behavior and survival under inherently uncertain conditions: in other words, not perfect predictions, but learning from prediction errors. According to the Bayesian reading of predictive coding, the extent to which these prediction errors can update prior models is regulated by the synaptic gain of prediction-error units. Thus, depending on environmental volatility, reduced prior precision biases the organism towards exploration, while increased prior precision leads to exploitation. From this perspective, the construction of one's world unfolds as an internal generative process that allows organisms to maintain models that are stable enough to guide behavior yet flexible enough to accommodate change. If uncertainty arises only with the reflective observer, how can this view explain how living systems – human and non-human alike – display adaptive sensitivity in the face of what we describe as the unpredictable, the unpredicted, or the indistinguishable? Q1

« 5 » Although many questions remain unanswered, these theoretical views are increasingly being substantiated by empirical findings. We see that the nervous system neatly distinguishes between the predictedness (surprisal), predictability (entropy), and predictiveness (or predictive power) of stimuli (Ahlheim, Stadler & Schubotz 2014; Ahlheim, Schiffer & Schubotz 2016; Kluger & Schubotz 2017). Some of our own studies have helped to differentiate neural processes underlying the three main phases of the prediction process: the generation of predictions (Boeltzig et al. 2025; Roehe, Kluger & Schubotz 2023), the processing of prediction errors (Schiffer et al. 2012; Siestrup et al. 2025), and the consequences of prediction-error processing such as model updating (Jainta, Zahedi & Schubotz 2024; Liedtke et al. 2025; Schiffer et al. 2013; Selvan et al. 2024; Siestrup & Schubotz 2023), model switching (Trempler et al. 2017, 2022), or model confirmation (Kluger et al. 2019; Kühn & Schubotz 2012).

« 6 » In Andrey Druzhinin and Diego Ramírez's portrayal of Humberto Maturana, human culture treats uncertainty as an undesirable state, reinforced by linguistic and educational practices that value stability and control. Notably, a comparable normative assumption is found in predictive-processing formulations of brain function, best illustrated by the so-called "dark-room problem": If organisms only minimized surprise, they would avoid novelty and exploration and ultimately end up in a dark room for maximum certainty until they died. This grim scenario is addressed by the introduction of the concept of "expected free energy," which assigns epistemic value to actions that temporarily increase uncertainty in order to improve future predictions (Friston et al. 2015). Alternatively, others have emphasized that agents may strive to maximize (Shannon's) mutual information rather than minimize entropy, thereby promoting active exploration and engagement with the environment to improve the fit between one's internal models and one's experiences (Little & Sommer 2013). Can the notion of a "difference that makes no difference" be reconciled with predictive brain architectures, for which a mismatch between expectation and experience is constitutive of learning? Q2

« 7 » The same mechanisms that allow the brain to reduce uncertainty also enable organisms to seek, explore and regulate it, linking uncertainty to curiosity and creativity, which expands the generative space for prediction (Constant, Friston & Clark 2023). It is noteworthy that both biological and cultural systems appear to be particularly attracted to an intermediate level of uncertainty and surprise, a "sweet spot" between monotony and chaos (Clark 2018; Vuust et al. 2022). At this intermediate level of prediction error, the brain faces a fundamental choice: whether to integrate an experience into existing predictive models or to infer a new latent cause (Gershman et al. 2017; Liedtke et al. 2025). These perspectives do not portray uncertainty as an "evil" deficit that needs to be eliminated, but rather as a resource that must be regulated in order to maintain exploration, learning, and engagement with one's environment.

« 8 » From the biocognitive perspective, uncertainty and prediction arise only in and for the observer. These are linguistic distinctions that occur when reflection transforms living into explanation. From a neuroscientific perspective, however, uncertainty and prediction are inextricably linked to the adaptive dynamics of the brain: uncertainty is estimated, prediction errors are processed, and learning unfolds. What begins with reflection for Druzhinin and Ramírez, for neuroscience, begins with life itself.

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Two Sides of the Same Coin: How Languaging Bridges the Nature/Culture Divide

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> Abstract • An appeal to normativity in linguistic interaction provides a way to avoid positing a strict nature/culture divide. This approach appears more consistent with the bio-logical foundations of Maturana's notion of languaging than with an appeal to the normative constraints of a cultural domain.

Handling Editor • Alexander Riegler

« 1 » Undoubtedly, uncertainty is a fundamental and characteristic feature of human cognition and language use. In this respect, I agree with Andrey Druzhinin and Diego Ramírez. At the same time, however, I would be cautious about following the authors in making a decisive reference to what generally could be termed "the human cultural domain" when seeking to explain the emergence of such uncertainty. While the authors extend Humberto Maturana's (1988) theory of languaging – which itself contains several explicit references to culture and the cultural – I wish to highlight an inherent risk in becoming explanatorily over-reliant on the presumed influence of a cultural domain.

« 2 » The issue at stake concerns the distinction between the natural and the cultural, as imposed by the authors, and whether such a distinction is fully explanatorily compatible with a Maturanian bio-logical approach[1] to languaging. For instance, the authors remark that "the cultural meaning of uncertainty" is essentially synonymous with the way uncertainty "arises as an ex-

1| Vincenzo Raimondi explains the notion of the bio-logical, which he takes to be central to Maturana's account of languaging, as follows: "[T]aking a bio-logical stance to account for interaction and language means making explicit the constitutive conditions of the phenomena related to them, by drawing on our understanding of the conditions of existence of autopoietic living beings" (Raimondi 2019: 20)