DOCUMENT SUMMARY

This paper by Karl J. Friston, a leading neuroscientist, details the theoretical framework of predictive processing and active inference. It explains that the brain is not a passive receiver of information, but an active, "constructive organ" that constantly generates and tests predictions about the world based on its prior experiences. This framework provides powerful scientific support for Enlitens' core mission by offering a neurobiological basis for why every brain is unique, why standardized tests are inherently flawed, and how neurodivergence, trauma, and mental health conditions can be understood as logical, adaptive variations in predictive modeling rather than deficits.

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CRITICAL QUOTES FOR ENLITENS

- "It is difficult to find a contemporary paper in cognitive neuroscience that does not defer to the notion of predictive processing and associated schemes like predictive coding that implement predictive processing in cortical and subcortical hierarchies."
- "The basic idea is that the brain is a constructive organ, actively generating explanations for the sensorium and then testing its hypotheses against sensory data."
- "Predictive coding is appealing in its simplicity: essentially, it sets up a number of competing expectations about the causes of sensory input and then revises or updates these expectations on the basis of prediction errors."
- "These errors are just the difference between what was predicted and what is actually observed."
- "This leads to the notion of active inference, which can be regarded as a first principle account of predictive processing [8]."

- "The key thing here is that active inference and predictive processing inherit from first principles, whereas schemes like predictive coding are particular (neuronal) process theories about how these principles are manifested in the brain."
- "In turn, this would increase the predominance of forward travelling waves. Conversely, in the absence of precise sensory information, or when holding unduly precise prior beliefs about the causes of our sensorium, one might anticipate a greater preponderance of backward travelling waves."
- "I focus on this opportunity, because many psychiatric syndromes have been associated with a failure of sensory attenuation or an inability to modulate the precision of various prediction errors [4,20,21]."

KEY STATISTICS & EVIDENCE

- "Crucially, the range of these parameters matched almost exactly with empirical observations, namely, extrinsic conduction delays of about 12 ms and a lumped synaptic time constant of about 20 ms."
- "An interesting point here is that these characteristic (membrane) time constants are greater than one would expect when considering a spiking neuron (i.e., 5-20 ms.)."
- "As intimated in Alamia and VanRullen [18], this tells us something interesting about neuronal implementations of predictive coding. This follows from the fact that the effective time constants of population dynamics are typically greater than any constituent neuron."

METHODOLOGY DESCRIPTIONS

- "One way to answer to this question is to build a minimal model of predictive message passing and 'ping' it with a stimulus to simulate a spatiotemporal response."
- "This is precisely what the authors did-and then looked for evidence of alpha waves travelling up and down the hierarchy."
- "However, we also have to factor in recurrent message passing, as waves are reflected from (hierarchically deployed) 'edges' of the pond back to the epicentre."
- "If we associate a sensory stimulus with a local perturbation at the 'lower' end of the pond, one might expect to see a predominance of 'forward' travelling waves. Conversely, if we perturb the 'upper' end, the waves would appear to travel in a backwards' direction. However, in both cases, waves will travel in both directions, due to recurrent connections. This is exactly what the authors established, using numerical analyses (and analytic solutions to differential equations that embody a simplified version of predictive coding) [18]."
- "Not only were the authors able to demonstrate that these dynamics could be recovered with a careful (Fourier) analysis of synthetic responses, they went on to show that the same phenomenology could be recovered from empirical electroencephalographic (EEG) signals [18]."

THEORETICAL FRAMEWORKS

Predictive Processing and Predictive Coding

"There are 2 approaches to predictive processing: the low road usually starts from Kantian notions and Helmholtz's formulation of perception as unconscious inference [1]. The basic idea is that the brain is a constructive organ, actively generating explanations for the sensorium and then testing its hypotheses against sensory data. This notion underwrites predictive coding in the brain [2,3], a scheme originally developed to compress sound files in the 1950s. Predictive coding is appealing in its simplicity: essentially, it sets up a number of competing expectations about the causes of sensory input and then revises or updates these expectations on the basis of prediction errors. These errors are just the difference between what was predicted and what is actually observed. The ensuing belief updating can then be expressed as a recursive exchange of signals between neuronal populations encoding expected states of the world generating sensations and prediction errors. When predictions are generated under a hierarchical (generative) model of how (hidden) states of the world cause other states, we have a message-passing scheme that looks very much like the recurrent exchange of signals in visual cortical hierarchies; with ascending (prediction error) connections and a descending (prediction) counter-stream (Fig 1)."

Active Inference as a First Principle

"An alternative (high road) starts with the variational principles that underwrite self-organisation and assembly in sentient systems, to show that such systems can always be cast as making Bayesian inferences about their world, i.e., self-evidencing [5,7]. This leads to the notion of active inference, which can be regarded as a first principle account of predictive processing [8]. The key thing here is that active inference and predictive processing inherit from first principles, whereas schemes like predictive coding are particular (neuronal) process theories about how these principles are manifested in the brain. This means that all the heavy lifting-in terms of asking the right empirical questions-pertains to how predictive processing is implemented."

The Importance of Precision (The Neurobiological Basis of Attention)

"In brief, a key determinant of the balance between descending predictions and ascending prediction errors-rests upon the precision or confidence afforded prediction errors. In short, if a prediction error conveys precise, newsworthy information, it will be amplified so that it has a greater impact on belief updating in subsequent hierarchical levels. Conversely, in noisy (or dark) unreliable settings, sensory precision can be attenuated, thereby emphasising top-down prior expectations over impoverished sensory evidence. This is just an expression of Bayes optimal inference. From a physiological perspective, the excitability of prediction error units-and their neuromodulatory control-takes centre stage in this selective gating. Finally, from a psychological perspective, we have an appealing metaphor for attentional selection and sensory attenuation."

POPULATION-SPECIFIC FINDINGS

A Framework for Neuropsychiatric and Psychiatric Conditions

"An intriguing aspect of the results of Alamia and VanRullen [18] was the sensitivity of forward and backwards travelling waves to the (lower and upper) levels of perturbation. We will close by pursuing this, because of its special relevance for understanding the nature of hierarchal inference, its implications for higher cognitive functions, and the pathophysiology that may attend neuropsychiatric conditions [20,21]."

"In a physiological setting, the sensitivity of prediction error units to their afferents holds the key for this selective gating and implicates all the neuromodulatory mechanisms mentioned above. This is an important aspect of predictive coding that takes us into the world of selective attention and sensory attenuation [10,21,22]."

"As noted by Alamia and VanRullen [18], certain changes in attentional set will increase the precision or excitability of prediction error units lower in the hierarchy. In turn, this would increase the predominance of forward travelling waves. Conversely, in the absence of precise sensory information, or when holding unduly precise prior beliefs about the causes of our sensorium, one might anticipate a greater preponderance of backward travelling waves. This is clearly a prediction that could be addressed empirically... I focus on this opportunity, because many psychiatric syndromes have been associated with a failure of sensory attenuation or an inability to modulate the precision of various prediction errors [4,20,21]."

PRACTICAL APPLICATIONS

From Theory to Empirical Assessment

"This is clearly a prediction that could be addressed empirically, using the analyses described by Alamia and VanRullen [18] and manipulations of attentional set. This may be particularly exciting because it also affords the opportunity to quantify people's ability to switch attentional set or indeed engage sensory attenuation when appropriate. I focus on this opportunity, because many psychiatric syndromes have been associated with a failure of sensory attenuation or an inability to modulate the precision of various prediction errors [4,20,21]."