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Placing meta-stable states of consciousness within the predictive coding hierarchy: The deceleration of the accelerated prediction error

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ABSTRACT

While many studies have linked prediction errors and event related potentials at a single processing level, few consider how these responses interact across levels. In response, we present a factorial analysis of a multi-level oddball task – the local-global task – and we explore it when participants are sedated versus recovered. We found that the local and global levels in fact interact. This is of considerable current interest, since it has recently been argued that the MEEG response evoked by the global effect corresponds to a distinct processing mode that moves beyond predictive coding. This interaction suggests that the two processing modes are not distinct. Additionally, we observed that sedation modulates this interaction, suggesting that conscious awareness may not be completely restricted to a single (global) processing level.

1. Introduction

1.1. Prediction

Predictive coding, and the associated free energy hypothesis (Friston, 2010), is one of the most prominent theories in cognitive neuroscience. Central to the theory is the notion that we are continually predicting what is likely to fall next on our sensory receptors (or more generally, the previous layer in a processing pathway). Thus, predictions are enforced top-down, while Prediction Errors (PEs) manifest bottom-up, signalling that a prediction has been infringed, see Fig. 1, Panel C.

It has been argued that evoked responses reflect the confounding of expectations (Chennu et al., 2013; Friston, 2005); i.e. that they are the electrical manifestation of the brain signalling a Prediction Error (PE) (Friston & Kiebel, 2009; Friston, 2010) (strictly a precision-weighted prediction error (Feldman & Friston, 2010)). Accordingly, a number of Event Related Potential (ERP)

Abbreviations: ERP, event related potentials; PE, prediction error; GW, global workspace; RFT, random field theory; FWE, family wise error; SPM, statistical parametric mapping

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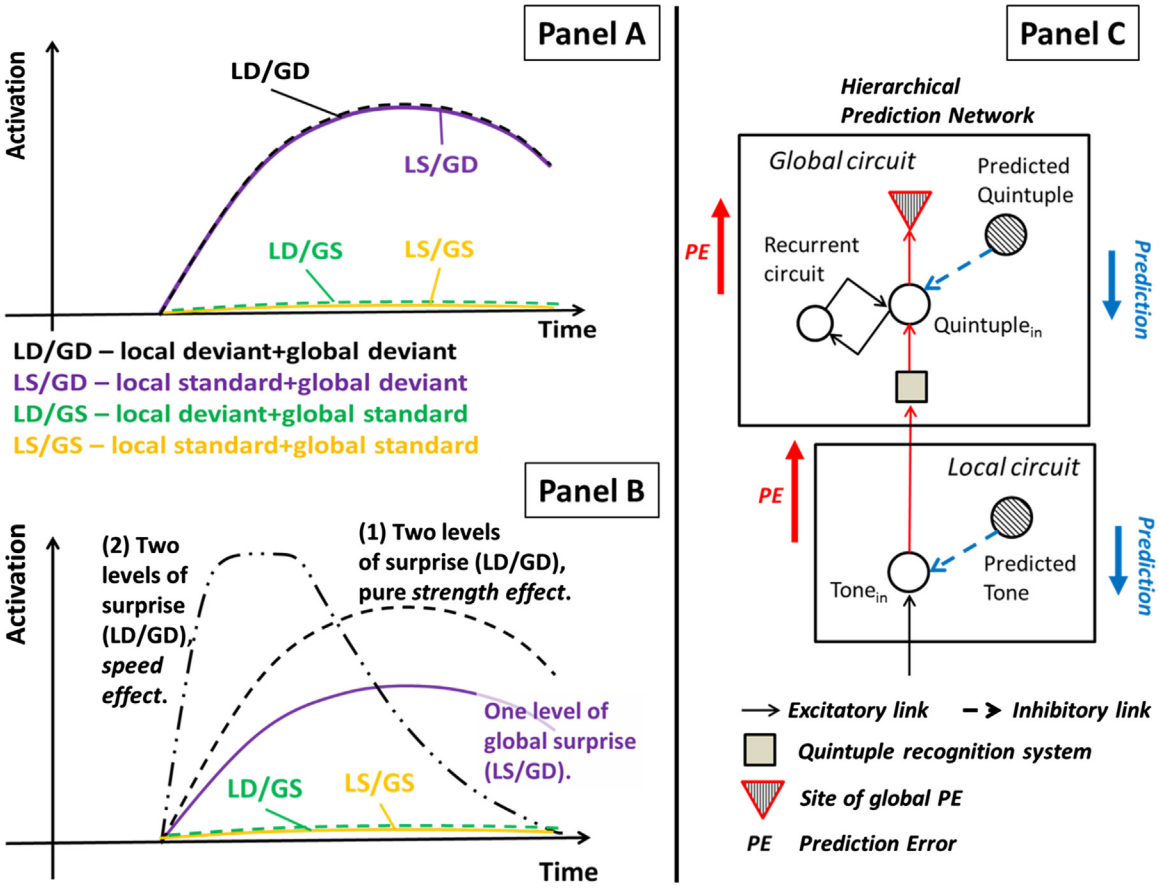

Fig. 1. Caricatures of ERP effects and neural framework. (Panel A): a particular non-interaction P3 pattern, showing a main-effect of global regularity on the P3, but neither a main-effect of the local regularity, or an interaction between the two factors. (Note, the local effect/mismatch negativity is not included in this depiction to simplify presentation.) (Panel B): potential local × global interaction pattern for the P3 response. Time series (1) shows a pure strength effect and time series (2) a speed effect, with accelerated P3. (Panel C): fragment of a putative neural architecture that could underlie the local-global effect. LD: Local Deviant; LS: Local standard; GD: Global Deviant; and GS: Global Standard.

experimental paradigms have been argued to directly engage this Prediction – Prediction Error (PE) system. A classic example of this is an auditory irregularity (oddball) task, which induces a Mismatch Negativity (MMN) response to an unexpected (so called *deviant*) tone presented within a train of (standard) stimuli (May & Tiitinen, 2010; Näätänen, Gaillard, & Mäntysalo, 1978; Näätänen, Paavilainen, Rinne, & Alho, 2007). The MMN is an increased negative deflection in the ERP, which arises soon (< 200 ms) after the eliciting (deviant) stimulus, with a source in auditory cortices. In addition, the MMN is not classically viewed as involving the long distance neural exchanges argued to characterise access to a Global Workspace (GW), which putatively underlies conscious experience (Dehaene, Kerszberg, & Changeux, 1998).

Importantly, classic MMN experimental paradigms typically only consider one level of surprise. However, in real-world cognition, a single prediction is typically relevant at many different levels of processing, and indeed any resulting infringement of that prediction induces an error at many levels and many different temporal frames. For example, after the following partial sentence, “The ball rolled to John, and he ….”, the listener may predict that the sentence would be completed with a phrase such as, “kicked it”. However, hearing “picked it up”, would confound a lower level contextual prediction that John is playing football, as well as a higher level broader frame of narrative context that John is in a country that does not play rugby.

This kind of cross-level error is absolutely the norm in real-world cognition, and in this respect, the vast majority of ERP experimental work on prediction and PEs oversimplifies by only considering one level of error. Thus, to fully characterise the predictive coding framework, it is essential to understand how errors propagate in the prediction hierarchy. In particular, while experimentally manipulating different levels of surprise *in isolation* is clearly important, it can never *fully* reveal the underlying neural system and predictive architecture – interactions between levels need to be considered.

1.2. Hierarchy and interactions

The cognitive processes that we will explore are two levels of prediction, which are called *local* and *global* in the literature. More fully, the local-global paradigm (Bekinschtein et al., 2009; Chennu et al., 2013) is a recent extension to auditory irregularity tasks that