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Spotlight Commentary

GNW theoretical framework and the "adversarial testing of global neuronal workspace and integrated information theories of consciousness"

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A recent publication in Nature (Cogitate et al. 2025) aimed at enriching the progressive build-up of a valid theory of conscious processing using valuable multicentric experimentation and massive data-sharing open to new analyses (Bryant and Whyte 2025). It is important to stress that several of the analyses reported in this Nature article validate key predictions of the Global Neuronal Workspace Theory (GNWT) including (i) transient ignition following stimulus onset in the predicted time-window (200-800 ms), (ii) irrespective of stimulus duration and (iii) of stimulus relevance, as well as (iv) decoding of "*conscious content in visual, ventrotemporal and inferior frontal cortex, with sustained responses [. . .] and content specific synchronization between frontal and early visual areas*." In other words, this article confirmed that stimuli that are clearly consciously visible elicit a brain-wide activation and synchronization between sensory areas and prefrontal cortex, even in the absence of task relevance, validating a non-trivial prediction of the GNWT. Also, given that this study only used clearly visible stimuli, it could not test the most central predictions of the GNWT, which tackle the critical contrast between conscious and non-conscious processing. Hence, several conclusions drawn by the authors about GNWT predictions need to be reconsidered.

GNW ignition after stimulus offset

The GNWT predictions schematized in Fig. 1 of the Nature article assume that GNW activation should show two successive peaks, reflecting two consecutive ignitions, respectively associated with stimulus onset and stimulus offset. While ignition after stimulus onset is indeed a core prediction of GNWT (Dehaene et al. 1998; Dehaene and Naccache 2001; Dehaene et al. 2003; Dehaene et al. 2006; Dehaene and Changeux 2011), offset ignition is not. Such an offset ignition is only predicted to occur if the participant is consciously attending to this offset event. In the Nature paper, several factors reduced the likelihood of a systematic awareness of stimulus offset. Indeed, in order to prevent post-perceptual processing ("no report" condition), the key analyses were performed on task-irrelevant non-target stimuli presented for long and variable durations (500, 1000, or 1500 ms), without any motivation for the participant to attend to stimulus offset. In these conditions, a systematic awareness of stimulus offset seems unlikely (as stressed on p.122 of the Supplementary Online Material of (Cogitate et al. 2025) by S.D.). Most importantly, none of the simulations of the model (Dehaene et al. 1998; Dehaene and Naccache 2001; Dehaene et al. 2003; Dehaene et al. 2006) and none of the experimental recordings (Dehaene and Changeux 2011; Mashour et al. 2020) revealed a definite offset ignition. Thus, the presence of ignition at stimulus offset cannot be taken as a central and discriminative prediction of GNWT, and its absence in the data is not a major issue for the theory—it would only be if the task enforced a systematic awareness of stimulus offset, or if it could otherwise be proven that the offset did not trigger any form of ignition despite awareness of this offset.

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Lack of decoding of some attributes of conscious content in PFC

While several attributes of conscious content could be decoded in prefrontal cortex (PFC) areas, as predicted by GNWT, the lack of decoding of stimulus category and orientation was highlighted in the Nature paper as a "key challenge" to the theory. While GNWT predicts that all consciously perceived attributes should be decoded from GNWT areas, including PFC, it is crucial here, however, to take into account several methodological and physiological factors that we previously mentioned in the context of a discussion of the causal effects of PFC stimulation on conscious content (Naccache et al. 2021). Decoding from functional magnetic resonance imaging (fMRI) , magnetoencephalography (MEG), and intracranial electroencephalography (iEEG) measurements is much easier in visual areas where neural coding is structured according to a mesoscopic columnar organization of neurons with shared selectivity; indeed, decoding from those areas is even possible under non-conscious conditions (Dehaene et al. 2001; Salti et al. 2015; King et al. 2016), raising the possibility that the decoding success there, which is discussed as positive evidence for Integrated Information Theory (IIT), could have arisen from purely non-conscious processes. By contrast, decoding from PFC areas is much more difficult because there is no strong evidence for columnar organization in the PFC, where neurons selective for different stimuli are characterized by mixed selectivity (Wang 2022). The most solid way of testing rigorously decoding predictions of GNWT across distinct cortical networks relies in recording large sets of single-cell resolution, such as neuropixels or related technologies in rodents, non-human primates, and humans.

Duration of stimulus decoding

In the Nature paper, there is a mention of possible transient periods of "silent state." Such states may happen, but they are not necessary and do not constitute a mandatory prediction of GNWT. Indeed, GNWT predicts that as long as you are conscious of a given content, this content is explicitly encoded in GNW activity in an explicit way (Naccache 2018). So as long as a participant is continuously aware of the current stimulus, GNWT predicts a parallel continuous decoding of it from GNW areas (notably prefrontal areas). But if participant's GNW moves from this content to another one, the stimulus should not be decoded from GNW areas. Here, the long duration, monotonicity, and task-irrelevance of the stimuli enhance the likelihood of the latter possibility, i.e. frequent lapses in stimulus awareness. However, since no subjective reports or other evidence were collected about the contents and dynamics of consciousness in this task, it is difficult to draw any strong predictions on GNWT. Such silent states may play a role in working memory, but they are neither a necessary nor a mandatory prediction of GNWT.

GNWT is a model grounded on explicit molecular hypotheses

Finally, one of the most interesting computational aspects of GNWT emerge from its enrooting in explicit molecular elements, which gives it strong biological realism and testability. In the initial (Dehaene et al. 1998; Dehaene and Naccache 2001; Dehaene et al. 2003) and more recent GNWT formal models (Volzhenin et al. 2022; Klatzmann et al. 2025), the molecular mechanisms proposed have led to rich theoretical predictions and to original experimental demonstrations (Koukouli and Changeux 2020). They include the allosteric transitions of postsynaptic receptors, the balanced excitatory-inhibitory receptors, the AMPA-NMDA glutamate receptors ratio, the hierarchical modulation of the reward and vigilance mechanisms . . . among others, which offer exquisite clues for experimental testing of GNWT in both animals and humans under normal and pathological conditions. Also, the spontaneous activity which emerges from this molecular background is anticipated to play a critical role in the ignition process (Dehaene and Changeux 2005).

In short, we felt important to provide readers of the Nature article with these comments that make the overall interpretation of reported results more balanced, in order to give access to a fair adversarial testing on both theoretical and experimental grounds. The late Martin Karplus, in one of his last papers, compared the understanding of the complex behavior of a worm to that of protein folding. The main issue is simulation of the outcome of a formal representation of the system that we referred to early on as a "formal organism" (Changeux and Dehaene 1989). The adversarial testing of two theories aimed at explaining the subjective nature of conscious processing requires the confrontation of the formal neuronal organisms that represent them, and the simulation of the behavioral tasks they are able to pass (Dehaene and Changeux 2005; Koukouli and Changeux 2020). Because this adversarial collaboration approach looks very valuable, it seems all the more important to highlight the aspects on which this first effort might have fallen short and to provide advice on what could improve the robustness of the present and future approach: testing the most central predictions of theoretical models on the specific processes that they aim to explain.

Author contributions

Lionel Naccache (Conceptualization [equal], Writing—original draft [equal], Writing—review & editing [equal]), Xia-Jing Wang (Formal analysis [equal], Writing—review & editing [equal]), Jean-Pierre Changeux (Conceptualization [equal], Writing—original draft [equal]), Claire Sergent (Formal analysis [equal], Writing—review & editing [equal]), Stanislas Dehaene (Formal analysis [equal], Writing—review & editing [equal]), and Michele Farisco (Formal analysis [equal], Writing—review & editing [equal])

Conflict of interest

L.N. and S.D. are co-inventor on patent 2019 EP 2983586 ("Methods to monitor consciousness"); and are shareholders of NeuroMeters, a company that applies these methods in clinical practice. None of these affiliations impose restrictions on publication or present conflicts of interest related to this study. The other authors declare no competing interests.

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