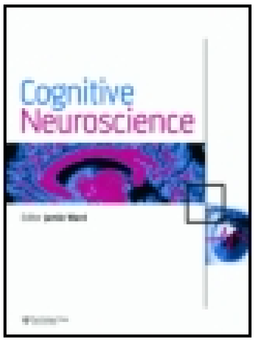

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COMMENTARY

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Explaining hyper-sensitivity and hypo-responsivity in autism with a common predictive coding-based mechanism

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ABSTRACT
Ward's signal detection theory-based framework elucidates some aspects of interindividual differences in sensitivity, but, we argue, obscures others. Specifically, it disregards the important challenge of inferring the meaning of sensory inputs. Within Bayesian predictive coding accounts, the meaning is given by inferences to more deeply hidden causes of sensory inputs and is generally the basis for initiating context-appropriate (e.g., social) behavior. As such, when inference of hierarchical causes is hampered, as accounts of autism based on deficient precision estimation imply, a form of hyporesponsivity can emerge (together with the hypersensitivity already highlighted by Ward).

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Autism; hypersensitivity; predictive coding; hierarchical bayesian inference

Ward (2018) helpfully distinguishes three types of sensory sensitivity that differ between individuals (or disorders), but that are often confounded in the literature: *Behavioral sensory sensitivity* (referring to psychophysical detection/discrimination), *subjective sensory sensitivity* (concerning self-reported experience), and *neural sensory sensitivity*. However, what is not fully captured in any of these are differences in what we could call *behavioral responsivity*, seen for example in autism as behavioral hypo-responsivity. This refers to the 'external' (e.g., parent or caregiver) reports of the absence of context-appropriate behavioral responses. One could assume this falls under *behavioral sensory sensitivity*, but the issue here is more complex than the low-level psychophysical detection and discrimination in Ward's definition of this category. It is about inferring the meaning or hidden cause of a sensory stimulus using deeper hierarchical generative models (as in predictive coding), rather than just detection or discrimination of mere sensory stimuli. In general, this type of inference is required for typical, context-appropriate behavior (if not the agent is condemned to a simplistic stimulus-response type of behavior). As an example, one could think of a type of social situation that is not recognized (inferred) as such and hence the socially expected response for this type of behavior is not activated. Similarly, the inability to infer certain emotions as hidden causes of one's own interoceptive inputs would prevent the appropriate action (an emotional response) from being initiated. Typical responses to stimuli tend to depend on inferring their deeper hidden causes. As we will see next, inferring hierarchical causes is hindered when the ability to flexibly define the weight of sensory inputs (precision) is impaired, as hypothesized to be the case in autism (Hohwy & Palmer, 2014; Van de Cruys et al., 2014).

Ward's assertion that the goal of the agent is '*maximising behavioral sensory sensitivity (because this is functionally adaptive) whilst minimizing neural sensory sensitivity (because a high amount of neural responsiveness is metabolically costly)*' sounds intuitively right. But behavioral sensitivity of what? Not every perceptual difference or change is something that one should notice/resolve. That would make for a very inefficient organism. Worse yet, which perceptual difference is relevant will depend on the context. The signal detection theory (SDT) analysis overlooks the crucial issue of figuring out what, in a given context, is relevant (signal) and what is noise (variability irrelevant to current concerns). This conception of noise as something context-

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and model-dependent (Jost, 2004) instead of objectively defined is beyond the reach of SDT analysis. Noise is given in the latter, rather than being actively (de)constructed. Indeed, honing in on meaning understood as inferring the hidden cause of sensory inputs (instead of the mere sensory inputs themselves) will require disentangling signal and noise (Van de Cruys, Van der Hallen, & Wagemans, 2017). This is a fallible process that relies on differential precision-weighting to, for example, disregard certain inputs as inconsequential to the task at hand (understood as a set of activated predictions). Relevance can be defined as the extent to which a piece of evidence (sensory inputs) should change the current inference (cf., Bayesian inference; Hohwy, 2017). This relevance, of course, is not present but should be learned from (changing) regularities in the sensory input, specifically in the precisions or expected (inverse) variances. Hence, it is the meaning or relevance of sensory stimuli that remain undifferentiated, impairing inference to deeper causes and access to context-appropriate actions that can efficiently reduce prediction errors. Even simple dichotomous perceptual decisions require inference to a more abstract category based on uncertain inputs. Indeed, we see that already in those cases, autistic individuals will show a reluctance to initiate a response, expressed as increased reaction times and higher response conservativeness (Pirrone, Dickinson, Gomez, Stafford, & Milne, 2017). Note that all of this also means that, in the context of predictive processing, Ward's dichotomy between (minimizing) neural sensitivity and (maximizing) behavioral sensitivity is a false one, as neural plasticity is necessary to optimize sensory sensitivity, cf., hierarchical Bayesian inference. The reason why deep hierarchical Bayesian inference (as in predictive coding) is needed is that an SDT approach cannot deal with the fact that agents operate in changeable and volatile environments.

If precision-weighting is deficient in autism, an SDT analysis which only considers (multiplicative or additive) *physiological* noise in the system, cannot explain the challenge of disentangling signal and noise in a volatile world in autism and the coexistence of *behavioral* hyporesponsivity with increased *subjective* sensory sensitivity (sometimes together with *neural* sensory sensitivity). Namely, prediction errors with inappropriately estimated precision will lead to overspecific, overfitted internal models that will less efficiently explain away sensory inputs of, for example, social situations that always vary in their sensory details. The sparse, generalizable hidden causes that explain inputs best are not formed (or properly applied). This will be expressed as increased cortical activity (especially in the lower level regions, as found in autism) and an aversive sense of sensory overload (trouble ignoring non-informative variability). Inferring slow-changing, deeper causes would typically also give the agent a sense of continuity (and self) in the face of fast fluctuating sensory inputs. It keeps the agent from being ceaselessly swayed by the sensory flood of the here and now. In autism, the continuity and predictability often have to be artificially created by imposing repetitive patterns to the low-level sensory flow, using 'cycling' movements.

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