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COMMENTARY



Sensory sensitivity: Should we consider attention in addition to prediction?

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ABSTRACT

Ward (this issue) proposes a signal detection framework to explore sensory sensitivity across different conditions and links it to the predictive coding theory. More generally, however, perception is determined not only by sensory input and by prediction or prior knowledge, but also by behavioral relevance. We argue that selective attention, the process that allows us to prioritize the processing of behaviorally relevant over irrelevant information, should be taken into account when considering individual differences in sensory sensitivity.

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Why are some people more likely than others to have an abnormally intense or adverse reaction to simple sensory stimuli? In his Discussion paper, Ward (this issue) offers a comprehensive framework to unify evidence on sensory sensitivity at different levels and across several conditions. According to Ward, individual differences in sensory sensitivity can be understood by considering the perceptual processing of neural signal and neural noise.

$$O = K(S) \cdot (1 + Nm) + Na$$

Ward links the signal detection framework to several theoretical models including the predictive coding theory. According to this theory, sensory sensitivity is related to differences in perceptual processing of the neural signal (i.e., $K(S)$). More specifically, predictable sensory stimuli are postulated to have a sparser neural representation, which is supported by studies reporting attenuated sensory neural activity for predicted relative to unfamiliar or unexpected information (Kok, Jehee, & de Lange, 2012; Summerfield, Trittschuh, Monti, Mesulam, & Egner, 2008). Differences in neural sensory sensitivity are then thought to be related to differences in the balance between priors and sensory input. Inadequate prediction models have indeed been found in several conditions linked to atypical sensory sensitivity, such as autism (e.g., Pellicano & Burr, 2012; van de Cruys et al., 2014).

Perception, however, is not only influenced by sensory input and priors, but also by the relevance

of the sensory input for our current goals. Predictive coding models that include this effect of attention (Friston, 2009; Rao, 2005), suggest that it can boost the precision of predictions, resulting in increased weighting of sensory signals that are behaviorally relevant ('endogenous' attention) or sensory salient ('exogenous' attention). While predicted stimuli evoke *reduced* neural activity, activity in sensory regions is *higher* for attended relative to unattended information (e.g., Corbetta, Miezin, Dobmeyer, Shulman, & Petersen, 1990; Reynolds & Heeger, 2009). In an elegant fMRI study, Kok, Rahnev, Jehee, Lau, and de Lange (2012) independently manipulated attention and prediction, showing that attention can silence the sensory attenuating effect of prediction. Their results suggest that attention (i.e., whether a signal is behaviourally relevant) and prediction (i.e., whether a signal is likely to be presented) act together synergistically to improve the precision of sensory signals. Translating this into individual differences, sensory sensitivity may not only result from the inability to predict the sensory experience, but also from the inability to prioritize the processing of information that is sensory salient or behaviourally relevant.

There is evidence across multiple conditions and methodologies that inadequate attentional priority maps can be related to sensory (hyper)sensitivity. For instance, atypical attention processes seem to be among the earliest symptoms of autism (Elison

et al., 2013; Zwaigenbaum et al., 2005; see also van de Cruys et al., 2014) and have been found in children with Attention deficit hyperactivity disorder (ADHD) who also frequently report sensory hypersensitivity (i.e. Bijlenga, Tjon-Ka-Jie, Schuijers, & Kooij, 2017). Furthermore, patients with mild traumatic brain injury report selective attention impairments as well as sensory hypersensitivity (Lundin, de Boussard, Edman, & Borg, 2006). Also, ADHD traits such as distractibility correlate with self-reported subjective sensitivity in the general population (Panagiotidi, Overton, & Stafford, 2018). These studies suggest that the inability to prioritize the processing of relevant over irrelevant information may be related to atypical subjective sensory sensitivity.

The suggested relationship between attentional priority maps and sensory hypersensitivity is further supported by neuroimaging research of the salience network. This large-scale brain network is involved in the detection of relevant sensory input as well as attentional filtering of distractors (Menon, 2015). In line with the behavioral research, we propose that abnormalities within this network could lead to inadequate attentional templates and therefore also to sensory hypersensitivity. Indeed, across conditions salience network abnormalities were linked to reduce attentional control (Bonnelle et al., 2012; Qian et al., 2019) and sensory hypersensitivity (Green, Hernandez, Bookheimer, & Dapretto, 2016).

In summary, several studies point to a relationship between selective attention and sensory sensitivity in the neurotypical population as well as in individuals with developmental disorders and in patients with acquired brain injury. Attention and prediction likely join forces to support the adequate processing of sensory input. It, therefore, seems important that a comprehensive account of sensory sensitivity considers the influence of attention.

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