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Alternative Bayesian accounts of autistic perception: comment on Pellicano and Burr

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Atypical sensory-perceptual experiences are a widely acknowledged, but poorly understood feature of autism. An enduring and still unresolved question is whether autistic perception should best be characterized in terms of reduced top-down influences on perception or, alternatively, enhanced bottom-up sensory-perceptual processes [1,2]. In their recent Opinion article, Pellicano and Burr [3] argue for the former. Their 'hypo-priors' account of autistic perception is essentially a Bayesian formalization of Mitchell and Ropar's earlier suggestion of 'attenuated influence by prior knowledge' [4]. However, bottom-up accounts of enhanced autistic perception can also be formalized in Bayesian terms [5] and this leads to similar predictions.

Figure 1 illustrates this point. The Bayesian approach to perception begins with a noisy sensory 'observation', represented here by a red Gaussian. This is multiplied by the prior (yellow Gaussian) to produce a posterior distribution (orange). The optimal estimate, represented by the centre of the posterior distribution, is shifted towards the prior, as indicated by the arrow in Figure 1a. Figure 1b illustrates the hypo-priors account. In this example, the prior is weakened by doubling its variance and, hence, the optimal estimate is much closer to the mean of the sensory observation. Figure 1c represents the alternative bottom-up account. Here, the strength of the prior is unaltered from the original example, but there is reduced sensory noise, indicated by a halving of the variance of the observation. The optimal estimate is identical to that in the 'hypo-priors' example – the symmetry arises because the relative influence of the prior is a function of the ratio of the variance of the prior to the variance of the observation [6].

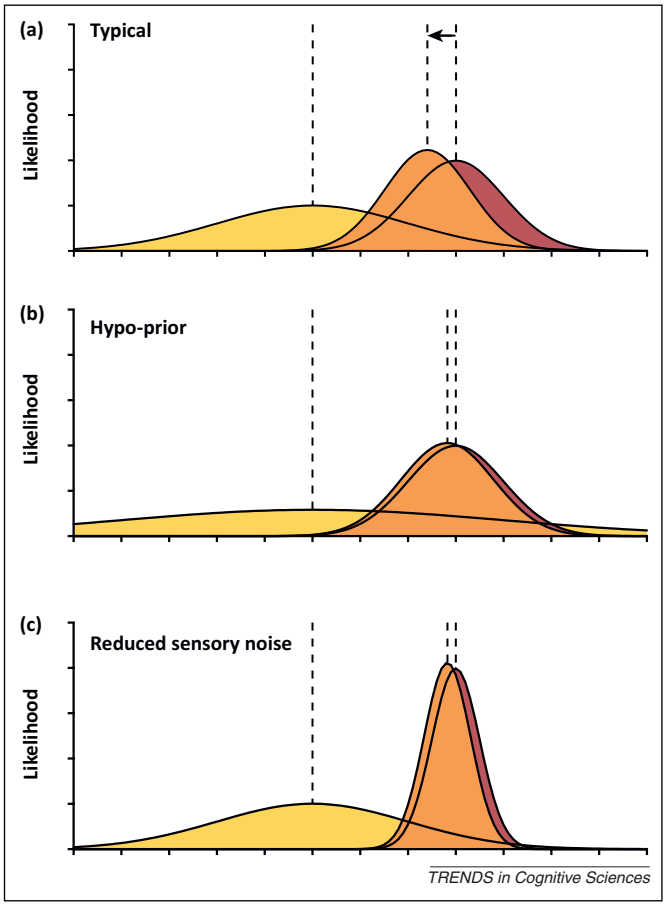

Figure 1. Individual differences in Bayesian perception.

So which account of autistic perception is correct? The above analysis suggests that top-down and bottom-up accounts may be difficult (although not impossible) to disentangle. One way forward might be to consider underlying neural mechanisms: hypo-priors could plausibly be attributed to reduced connectivity between different cortical regions [7], whereas reduced sensory noise might originate from increased lateral inhibition within cortical regions [8]. However, given the heterogeneity within the autism population, it is probably unwise to speak of 'autistic perception' as if there were only one mechanism. The Bayesian account allows for the possibility that similar atypicalities of perception may arise for different reasons in different autistic individuals.

None of this, however, answers the 'big' question – why do (some) autistic people have atypical perception? If the mechanisms of atypical perception really were independent of those responsible for the diagnostic characteristics of autism [1], then there should not be the association observed between autism diagnosis and atypical perception. At some level there must be a connection. Pellicano and Burr sidestep this issue, suggesting that their Bayesian account is relevant only to non-social features of autism (although see their Box 2). Yet, the effective and flexible use of prior knowledge is at the heart of everyday social interactions [9,10]. Perhaps more than any other aspect of autism, social impairment is in need of the Bayesian treatment.

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Response to Brock: noise and autism

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As Brock [1] suggests, it is indeed difficult to distinguish the action of top-down from bottom-up processes within a Bayesian framework. Either reducing the variance (noisiness) of the likelihood (bottom-up) or increasing that of the prior (top-down) has the same net result in changing their relative weighting in determining the posterior. Either possibility is, therefore, consistent with our framework. Although we welcome discussion of the causal underpinnings of altered sensation and perception in autism, we believe that an entirely bottom-up account is both unsupported by the evidence and limited in its explanatory scope.

Multiple factors contribute to the internal neural noise that determines the variance of the likelihood of a visual judgment, including photon shot-noise, optical distortions, thermal photoreceptor noise, neural transmission and processing noise, and sampling noise from the necessarily limited neural resources. The common consensus (e.g., [2]) is that animal sensory systems have evolved to perform optimally in their environment, so there is little room for further noise reduction. Reduced noisiness in autistic perception would require sensory systems built with superior components (or perhaps more of them). This is not entirely impossible, but it is not obvious from the available evidence. Indeed, the evidence from imaging and electroencephalography (EEG) studies suggests that the brains of autistic people are characterized by more noise than those of non-autistic people (e.g., [3]; also see [4,5]). Similarly, there is little psychophysical evidence for reduced noise in autism, which should lead to more precise psychophysical judgments in basic tasks that are uninfluenced by priors (see [4] for review).

The Bayesian model is often considered optimal in the sense that the priors are adjusted dynamically to reduce overall error. If the likelihood were less noisy in autistic perception, a functional Bayesian integrator would have to adjust the priors appropriately, in the same way that the priors of professional percussionists (who have enhanced temporal discrimination) are different from non-percussionists in discriminating temporal intervals [6], all leading to optimal performance. However, autistic perception does not always confer advantages [7], especially when prior knowledge is necessary to resolve perceptual ambiguities (e.g., [8]). To explain these data and to provide a more complete explanatory account of the perceptual experiences of autistic people (one that goes beyond the focus on enhanced, or hyper-, sensitivity in autism), Brock's account would require proposing reduced sensory noise in autism and atypicalities in the dynamic calculation of the prior, which would fail to take the reduced noisiness into account. Our concept of 'hypo-priors' [9] has greater explanatory power than existing bottom-up accounts, accounting not only for the reported hypersensitivity in autism, but also for a range of other sensory and other non-social symptoms.

Most importantly, contrary to Brock's suggestion, we believe that our account and the Bayesian framework more broadly has firm implications for understanding how autistic people represent information at all levels of the perceptual and cognitive system, including complex situations, such as social interactions. We chose, however, to begin our approach with the more tractable problem of perception, which is amenable to investigation with reasonably well-controlled stimuli, before extending these principles to the social realm.

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