Are Prediction Error Attenuations Domain-specific in Autism but Domain-general in ADHD?

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Abstract

Research on repetition suppression suggests that neural correlates of prediction errors (PE) in autism spectrum disorder (ASD) might be domain-specific with increased attenuations for faces compared to objects. Contrastingly, research assessing mismatch negativity in attention-deficit/hyperactivity disorder (ADHD) indicates a domain-general attenuation of PE. Therefore, we captured neural correlates of PE to colours and emotions in adults with ADHD or ASD to assess domain-specificity of PE attenuations. We extracted participant-unspecific precision-weighted PE and prediction strength (PS) for emotions and colours of presented faces separately using a generative model, specifically a Hierarchical Gaussian Filter (HGF). While we found neural correlates of colour precision-weighted PE and PS as well as emotion PS in the pooled sample regardless of diagnostic group, we did not find any differences in neural correlates of emotion or colour precision-weighted PE or PS between our groups. This null finding indicates intact neural correlates of precision-weighted PE in ASD and ADHD for both colours and emotions.

Keywords: prediction error; Bayesian Brain; predictive coding; autism; ADHD; face processing;

Introduction

In the last decades, several theories have postulated predictive impairments to underlie ASD, many of which were based in the Bayesian Brain framework (Cannon et al., 2021). A recent study demonstrated attenuated neural correlates of PE in autistic compared to non-autistic adults (Sapey-Triomphe et al., 2023). No research so far has investigated the domain-specificity, i.e., whether PE attenuations in ASD are specific to certain types of stimuli. However, research focusing on neural adaptation indicates a stronger attenuation for faces than objects (Ewbank et al., 2017). PEs signal a misfit between predictions, as indicated by neural adaptation, and reality; thus, attenuation of PEs could be domain-specific in ASD as well.

While less research has focused on PE in people with ADHD, there are several indications for a possible attenuation of its neural correlates. First, adolescents with ADHD showed attenuated reward PE processing (Hauser et al., 2014). Second, both auditory and visual oddball paradigms revealed decreased mismatch negativity amplitudes (Dang et al., 2024; Hsieh et al., 2021), which can be conceptualised as an indicator of PE (Cheng et al., 2016;). Last, neurobiological theories have emphasised attenuations in the catecholamine system as underlying impairments in ADHD (Ziegler et al., 2016). Both neurotransmitters seem to play a vital role in processing PE (Diederen & Fletcher, 2021). Specifically, attenuations of the dopamine system associated with ADHD could explain findings on reduced PE, suggesting a domain-general predictive impairment in ADHD.

Therefore, we investigated neural correlates of the strength of predictions (PS) and of PEs associated with violated predictions in ASD and ADHD in this preregistered study. Specifically, we aimed to assess domain-specificity of PE attenuations in ASD and ADHD as a possible differential marker with ASD showing domain-specific attenuations and ADHD showing domain-general attenuations of PE.

Method

We collected and analysed the data of 67 participants, 23 adults with ADHD (2 diverse or agender, 9 female, 12 male; 26.96 ± 1.51 years old; estimated IQ = 106.65 ± 2.23), 22 adults with ASD (14 female, 8 male; 29.36 ± 1.69 years old; estimated IQ = 114.98 ± 2.98) and 22 adults without any psychiatric diagnoses (comparison group COMP; 10 female, 12 male; 27.77 ± 1.22 years old; estimated IQ = 109.70 ± 2.10).

Participants completed a multi-feature roving visual mismatch paradigm (VMM) based on Stefanics and colleagues (2019) in the fMRI scanner. Their task was to press a button whenever they detected a change in the fixation cross and unrelated to the stimuli of interest. While participants attended the fixation cross, tetrads of faces were additionally presented for 200ms followed by 550ms of the fixation cross on its own. Each face in a tetrad portrayed the same emotion (fear or happiness) and was coloured in the same colour (pink or green). Blocks of 5 to 9 consecutive tetrads were coloured in the same colour and portrayed the same emotion, building up predictions. Between blocks, the emotion, the colour or both changed to elicit a mismatch reaction.

We used two Hierarchical Gaussian Filters (HGF, Mathys et al., 2014) to model belief trajectories about emotions and colours separately assuming Bayes-optimal parameters, similar to Stefanics and colleagues (2019). The HGF is a generative model of perceptual inference, allowing one to infer hierarchically related hidden environmental states that generate sensory inputs. PS is captured by the posterior mean of the belief on the second level ($\mu2$), while the pwPE at the second level ($\varepsilon2$) captures the update of PS on the second level (see Figure 1). Trial-by-trial PS and pwPE were added as parametric predictors in FSL FEAT (Jenkinson et al., 2012), together with the intercept, colour and emotion of the faces as well as six motion regressors extracted from fMRIPrep (Esteban et al., 2019). We used t-tests restricted to regions of interest (ROIs: bilateral anterior cingulate cortices, amygdalae, fusiform gyri, insulae and precunei as well as right supramarginal gyrus and posterior temporal gyrus) to evaluate group differences and task effects.

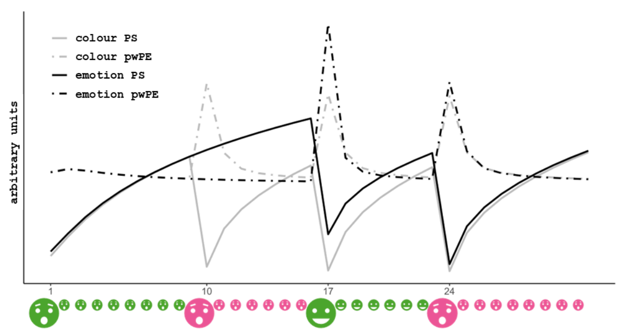

Figure 1: Trial-by-trial PS and pwPE.

Results

The ROI analysis considering neural correlates in the pooled sample, including all diagnostic groups, revealed several significant clusters of neural activation associated with colour PS and pwPE as well as emotion PS. Furthermore, we found a significant decrease in neural activation in the right fusiform gyrus with increased repetition of the same emotion and colour, indicating repetition suppression (RS, see Figure 2). However, we observed no significant differences in the neural correlates of PS, pwPE and RS between the diagnostic groups, neither in the hypothesis-guided nor in explorative whole-brain analyses.

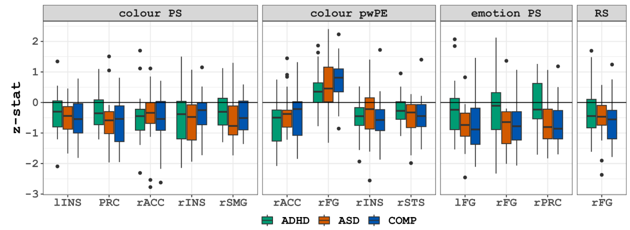

Figure 2: Subject-specific task-effects.

Discussion

Our brain constantly interprets the sensory input it receives and uses it to make predictions about the world. We induced predictions about emotions and colours for unattended, task-irrelevant faces in adults with ASD or ADHD as well as adults without any psychiatric diagnoses. Repeated presentation led to RS in the right fusiform gyrus in our sample. Furthermore, neural correlates of colour pwPE and PS were found in regions associated with face and emotion processing. While we observed no neural correlates of emotion pwPE, we found emotion PS to be associated with activation in the right precuneus and bilateral fusiform gyrus.

All investigated neural correlates were independent of the diagnostic status of our participants, indicating comparable neural correlates of PS and pwPE induced by colour and emotion of faces in adults with ADHD or ASD and adults without any psychiatric diagnoses. Comparable neural correlates of pwPE in ASD and COMP differs from a recent study where HGF parameters were extracted from subject responses (Sapey-Triomphe et al. 2023), while we used Bayesian-optimal parameters based on task-irrelevant faces. This discrepancy could suggest that differences between autistic and non-autistic people only emerge when stimuli are relevant to the task at hand. However, it is possible that the Bayesian-optimal parameters fit one group's cognition better than the others.

Nonetheless, we also did not observe previously reported RS attenuations in ASD (Ewbank et al., 2017) which were independent of the HGF parameters. Here, our task differs in the location of the relevant stimuli, with them being placed in the centre previously and in the periphery in our study, again suggesting that differences might only emerge under certain conditions.

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