Obligatory processing of task-irrelevant stimuli: a hallmark of autistic cognitive style within and beyond the diagnosis

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Work by Keehn & al. [Keehn17] couples a core symptom of autism spectrum conditions (ASC) – 'restricted and repetitive behaviour' – a product of autistic differences in level of perceptual organisation and fluidity of cognitive control – to behavioural and physiological indicators of differences in brain organisation in general and distribution of attention in particular. Specifically, Keehn et al. find, in ASC relative to controls, less alpha (8-12 hz) desynchronisation following behaviourally relevant targets, in relation to baseline alpha power following other stimuli in an ongoing stream of rapid serial visual presentation. This apparent reduction in alpha desynchronisation correlates with the restricted and repetitive behaviours subscale of the Autism Diagnostic Observation Schedule (ADOS), and is accompanied by a similar apparent absence of desynchronisation following stimuli adjacent to the attended location that share a behaviourally relevant feature, colour. These reductions in phasic alpha desynchronisation are accompanied by reductions in tonic alpha power in a relationship that apparently holds dimensionally across both autistic and non-autistic groups. A measure of repetitive behaviours less coarse than the ADOS might likewise reveal a transdiagnostic, dimensional nature of Keehn et al.'s relationship between reduced alpha desynchronisation and typical degrees of repetitive behaviour.

The challenge, of course, is how to relate these dimensional differences in physiology to similar differences in information processing and, thereby, in cognition and behaviour. In a neural network of sufficiently high entropy, individual neural units assume distinct, uncorrelated activation states when representing information. Because uncorrelated postsynaptic potentials tend to sum to zero on a macroscopic scale, information processing reduces EEG amplitude in general, and phasically reduces power in the brain's characteristic resonant frequency in the alpha band. As Keehn et al. note, GABAergic inhibition is in contrast associated with tonically greater alpha power in the resting state, in the absence of high information processing demand. Greater tonic resting alpha power therefore is associated with greater phasic alpha power reduction, or 'event-related desynchronisation'.

More generally, entropy within local neural networks is maximised when the balance between excitatory and inhibitory tone (E/I ratio) is optimal: in animal studies, imbalance in E/I decreases entropy of local neural networks as measured within arrays of intracortical electrodes [Shew11]. In humans, such decreased local-network entropy perturbs development of long-range networks of information transfer [Vakorin11], resulting in exactly the lack of task-related deactivation of the default-mode network [Deco14] that has been observed in autism. In keeping with the results of Keehn et al., these perturbations are in general dimensional, covarying with each other in the absence of clinical disorder and no doubt contributing to individual differences in cognitive style both within and beyond the categorical diagnosis of autism – a continuum that might be characterised coarsely as the difference between bottom-up, parietally dominated processing, low perceptual construal (sometimes termed 'central coherence', a distinct term for one and the same concept), and low psychological distance on the one hand and top-down, frontal biasing, high perceptual construal, and high psychological distance on the other. This major axis of human cognitive variation seems to covary not only with autism but also with cognitive sex differences, individualistic/collectivistic cultural differences, and even situational manipulations of psychological distance and level of construal.

An apparent lack of specific response to behaviourally relevant versus irrelevant stimuli can result from lack of response to relevant stimuli in particular, or from undifferentiated allocation of neural resources to relevant and irrelevant stimuli both. In this context of rapid serial visual presentation where a new stimulus arrives every 120 ms it seems impossible to differentiate these two complementary scenarios. The latter explanation, however, reframes autistic cognitive style as not unequivocally a deficit in selective processing of task-relevant stimuli but also an advantage in processing a broad field of stimuli, and is the more consistent with a broad corpus of evidence.

Our and others' work has suggested than such obligatory processing of task-irrelevant stimuli is the norm within the diagnostic category of autism, and more broadly, correlates with dimensional measures of autistic traits beyond the diagnosis and thus with a major axis of individual differences in perception, cognition and action. In a task of cued endogenous shifting of visual attention between hemifields, quantitative EEG [Belmonte00] and fMRI [Belmonte03] measures of secondary visual cortex's activation in response to task-related stimuli indicate less recruitment of finite neural resources away from task-irrelevant and towards task-relevant stimuli. In a task demanding distribution of visual attention across multiple perceptual features (spatial location, orientation, and colour), a delayed and prolonged time course of event-related fMRI fronto-cerebellar activation correlates with dimensional measures of autistic social and communicative traits not only in children with autism but also in their clinically unaffected sibs, and sibs' accuracy in the task lies between that of the typical and ASC groups [Belmonte10]. ***In short, ASC is characterised on fMRI and EEG measures by less differentiated response to task-relevant and task-irrelevant stimuli, and prolonged stimulus evaluation.***

In our own suite of experimental computer games designed to heighten children's motivation and thus ecological validity, amplitudes of late cognitive event-related potentials evoked by task-irrelevant stimuli correlate with dimensional and categorical differences in autistic traits, across two distinct visual tasks. In a result reported in 2011 at the International Meeting for Autism Research, in a go/no-go paradigm in which an enemy or friendly spaceship emerges from a 'wormhole' and the player must shoot or withhold fire, amplitude of P3b in response to the no-go (no behavioural response) stimulus correlates dimensionally with decreasing score on the 'Reading the Mind in the Eyes' Test as a main effect (r = -0.46, p < 0.01; Figure 1, top row) and as an interaction with decreasing Benton Test of Face Recognition scores, across ASC, clinically normal sibs of ASC, and normal control groups. In short, greater P3b amplitude in the no-go condition predicts more 'autistic' impairment in labelling of facial emotions and recognition of faces. In a separate study on visual selective attention to feature conjunction, Milne et al. [Milne13] likewise found in a population of normal young adults that decreasing difference between P3b to targets and P3b to non-targets is related to Autism Spectrum Quotient. In this same study, this P3b difference also correlated with efficiency (time per search item) in a visual conjunction search task. ***In short, autistic traits are characterised by less differentiated P3b response to targets and distractors.***

Further evidence comes from a variant of the Posner visual spatial attention paradigm in which the player mines asteroids (targets) that appear in validly or invalidly cued sectors of space, and avoids responding to visually distinct distractors. In an interaction of validity and group on amplitude of the posterior P2 (160-230 ms) – a visual ERP component associated with spatial grouping of objects [Kasai15] – the difference wave to invalidly minus validly cued targets (that is, targets that appear in areas of the visual field not flagged for behavioural relevance versus those that have been flagged) is strongly positive in controls and sibs but near zero in ASC (F(2,28)=3.442, p=.048; Figure 1, middle row), suggesting again that stimuli most likely to be of behavioural relevance do not received privileged processing. Moreover, the difference between the slow-wave (600-800 ms) ERP to targets and that to distractors is actually reversed in children with ASC (p < 0.05) and seems likewise in their sibs (p = 0.08), with distractors evoking a greater and more prolonged slow-wave

response than targets (Figure 1, bottom row). ***In short, in the context of tasks that demand broad distribution, integration, and/or rapid shifting of attention across a spatial field or in general amongst multiple perceptual channels, ASC is characterised by less differentiated P2 response to stimuli across relevant and irrelevant portions of the visual field, and autistic traits by prolonged evaluation of distractors.***

All this evidence, convergent across tasks and imaging methods, indicates that people with high levels of autistic traits perceive by a process of bricolage [Belmonte08], allowing many stimuli access to higher, more elaborated processing and from these many perceptual details building up a complete picture. This process confers benefits in performance on tasks that rely on such complete processing of details, such as visual conjunction search [Milne13] and more generally in the complete characterisation of a system in terms of all its component parts – a skill that Baron-Cohen has termed 'systemising' – but carries costs in tasks where early filtering based on top-down bias and prior expectation would, if sufficiently applied, keep perceptual/cognitive demand from overwhelming capacity. Again and again – most recently by Keehn et al. – correlations have been discovered byetween such basic non-social processes of attention and perception on the one hand and behavioural and psychometric measures of autistic traits on the other. Such relationships ought to compel us to recognise that the categorical deficits that are the most obvious, the most diagnostic, and the most debilitating are not necessarily the most ætiologically primary, or the most therapeutically accessible, and may emerge from extremes of dimensional variation in prerequisite, lower-level, earlier-developing skills.

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