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Editorial

Sensory and social features of autism – can they be integrated?

A diagnosis of an autism spectrum condition (ASC) is made on the basis of both social difficulties, in communication and interaction, and non-social difficulties, including sensory features and repetitive behaviors. A major challenge for the field is understanding the relationship between these – can both these aspects of ASC be explained under a single model? Is one aspect of ASC primary and the other secondary? Or do different causes drive the social and sensory components of this condition? In this special issue, researchers from across the autism field will consider this question, presenting data and theories on the relationship between sensory and social functioning in children and adults with ASC. The papers in this special issue provide a diverse range of approaches to tackling this complex problem.

Several of the studies in this special issue tackle the relationship between sensory and social processing in infancy and early childhood. Such a developmental perspective is essential if we hope to understand how these two domains interact, one affecting the other over ontogeny. Employing a high-risk infant-sibling design, Cheung and colleagues (Cheung et al., 2016) compared the visual search performance at 9 and 15 months of high-risk infants who would later develop ASC to those who would not develop ASC. Those who went on to develop typically exhibited better visual search performance at 9 and 15 months relative to those who did develop ASC. The link to autistic symptoms was specific. For instance, visual search performance did not predict other neurodevelopmental conditions, such as attention deficits or hyperactivity later in development. This study reveals an exciting developmental link between early visual perceptual differences, outside of the social domain, and later social difficulties. Future studies can begin to dig into the biological mechanisms underlying this developmental connection.

Jones and colleagues (Jones et al., 2017) extend this kind of prospective developmental analysis into early childhood. They examined hypothesized links between parent reports of sensory sensitivities at age two years and later electrophysiological indices of brain responses in face processing systems. They report the somewhat counterintuitive discovery that early parental reports of sensory hypersensitivity are correlated with increased responses and increased social approach at age 4 years. At first glance, this pattern of findings suggests that early hypersensitivity might well be beneficial or even protective against the social deficits that are central to ASC. But such an interpretation neglects the possibility that sensory hypersensitivity instead predicts enhanced attentional capture, similar to that seen in various anxiety-related conditions, by faces early in the development of those children with ASC. Thus, instead of being protective, the hypersensitivities instead represent a mechanism that drives abnormal levels of attention (in this case hypervigilance) towards faces. The prediction arising from this work is that these individuals will be more likely to experience anxiety symptoms in addition to ASC.

Engagement with social stimuli is also measures in a prospective study from Vernetti & colleagues, (Vernetti et al., 2017) in high / low risk children at 2 years who were followed up to confirm if there was an autism diagnosis at 3 years. Children's looking behavior was measured while observing gaze-contingent display where they could chose to see a person compared to a mechanical toy, or an engaged compared to a disengaged person or a predictable compared to an unpredictable person. Group differences emerged only in the predictability comparison, with typical children and high-risk children without autism showing a preference for the more variable stimulus, while infants later diagnosed with autism had no preferences. There were no detectable differences in social motivation towards the human and engaging stimuli in this sample. This argues against claims that social and motivational differences are primary in autism.

In a pair of papers, Baranek et al (2017) and Damiano-Goodwin et al (2017) report data from a longtundinal study of high and low risk sibs. Damiano-Goodwin et al examined the children at 18 months in a behavioural assessment of sensory seeking and social engagement, as well as resting state EEG; social difficulties were recorded again at 36 months. The results showed early sensory seeking was related to early social engagement and later social difficulties. Baranek reports data from the same sample at 24 months, and again finds that sensory seeking at early ages predicts later social difficulties. These two studies imply that sensory issues should be considered among the primary and early-developing components of autism.

Vivanti and colleagues (Vivanti et al., 2017) examined a central component of sensory / perceptual processing –habituation (the decrease in response to repeated presentations of the same stimulus) in three groups of participants. They compare preschoolers with ASC, those with Williams syndrome (a disorder caused by deletion of specific genes from chromosome 7 and characterized by mild to moderate intellectual disability and unique personality characteristics including "hypersociality") and typically developing preschoolers. Unique to ASC, they identified a pattern of less habituation of visual attention to repeated visual shapes, suggesting a basic abnormality in sensory processing.

While the critical large-scale, population-based studies have yet to be undertaken, investigators such as Guy and colleagues (Guy et al., 2017) have drilled down into one specific risk factor for the development of ASC, Fragile X syndrome (FXS). FXS is an X-linked, trinucleotide repeat expansion disorder involving FMR1 (fragile X mental retardation 1) gene. This is a leading single-gene cause of ASC. FMRP protein encoded by this gene regulates protein synthesis in neurons. The most prominent theory of FXS, mGluR theory, posits that many symptoms of the FXS are due to exaggerated neuronal responses to activation of mGluRs. Fragile X often features sensory integration problems, such as hypersensitivity to loud noises or bright lights. Guy and colleagues examined face processing in 12-month-old infants at high risk for developing ASC as a result of FXS, compared to 12-month-old infants at risk because they have an autistic sibling and 12 month olds with low autism risk. They find some differences in

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ERPS to viewing faces compared to toys, with the FXS infants showing a larger N290 amplitude than low-risk infants, and the infant-sibs showing a smaller N290 amplitude. This implies different types of face processing in infants with different autism risk factors, emphasizing the heterogeneity of autism spectrum conditions and implying different contributions of sensory and social processing in different groups.

Several studies in this special issue examine social and sensory issues in children and adults with ASC. Using questionnaires to measure sensory symptoms and autistic traits across 210 children with autism or sensory processing disorder or neither, Tavassoli et al (2017) find that Empathising Quotient scores are negatively correlated with Sensory scores, suggesting that sensory and autistic symptoms can be linked. However, the behavioral studies reported here offer contrasting results. For example, Ropar et al (2017) tested how children with ASC embody a hand under conditions of synchronous or delayed visual and tactile feedback. They find evidence for a developmental delay in visuotactile integration in autism, in that the ASC group (mean age 12.6 yrs) performed similarly to the mental-age matched group (mean age 7.9 yrs) but worse than the chronological age-matched group (mean age 12.7 yrs). Similarly, Ansuini et al, (2017) measured motor planning abilities in children with and without ASC (mean age 9.9 yrs) performing unimanual, bimanual and social reach-to-grasp tasks. They found no group differences in performance and found that IQ rather than autism diagnosis was the key predictor of grasp parameters.

In another study of sensorimotor function, Ansuini et al studied the kinematics of grasping movements under social and non-social conditions in children aged 7-12 years with and without ASC. They found no evidence for group differences in motor planning, which implies that impairment in social function can be seen in autism without differences in motor skill. Finally, Karaminis et al (2017) examined how young people with and without ASC (mean age 11.6 yrs) perceive the average emotion across a group of faces. They found no group differences in precision or accuracy, and computational modeling revealed similar strategies in both groups, which they believe argues against Bayesian perceptual theories of autism. Together, these studies suggest that differences in sensorimotor processing and perceptual integration are not always apparent when children with ASC are compared to age and IQ matched typical participants. These results imply that sensory and social difficulties may be independent in school-age children with ASC.

Studies of sensory and social features of autism in adulthood are also valuable in understanding how these might be linked. Lawson and colleagues (Lawson et al., 2017) measured if participants show after-effects to both social and non-social directional cues include gaze, head orientation, and object orientation. They found differences in participants with autism only in gaze orientation, which suggests a specific difference in social processing that does not generalise to other sensory systems. This, combined with the study of older children and adolescents suggests an interesting developmental profile whereby sensory and social deficits are inextricably intertwined early in development but become separate over childhood and into adolescence.

Two of the studies featured in this special issue utilize the most powerful techniques available to cognitive neuroscientists in order to explore brain and behavior linkages and test hypotheses concerning relationships between sensory processing and social difficulties. For instance, Linke and colleagues (Linke et al., 2017) examined—via resting state functional connectivity magnetic resonance imaging (rs-fcMRI)—characteristics of the auditory sensory processing systems and autistic social symptoms as measured via the autism diagnostic interview (ADI), social responsiveness scale (SRS), and autism diagnostic observations schedule (ADOS). Their analysis reveals intriguing linkages, at the level of brain function, between the patterns of functional connectivity that support auditory sensory processing and individual differences in the severity of social dysfunction within the diagnosis of ASC.

Green and colleagues (Green et al., 2017) take this a step further, adopting an experimental approach in which they used task-based fMRI of a cartoon task that asks the participant to appreciate sarcasm, and then provide a tactile (sensory) distractor to interrupt their social perception of the sarcasm, along with the instructions to attend to the cartoon or not. They found that, when stimuli were presented without instructions to attend, participants with ASC are less accurate than those with TD in judging sarcasm. Further, the brain imaging data revealed that tactile stimulation led to increased activity in a network of brain regions in TD participants including the left inferior frontal gyrus and insular cortex, the orbital frontal cortex, and dorsolateral prefrontal cortex dlPFC. But strikingly, in participants with ASC, these same ASC regions exhibited a decrease in activity. The attend instructions led to more typical activation patterns in ASC participants, suggesting that appropriate top-down control can normalize brain function, but overall the experiment demonstrated the mechanisms by which sensory stimuli can abnormally interfere with social information processing in ASC.

Finally, we round out our special issue, packed with excellent empirical articles, with a set of theoretical, integrative reviews that present different perspectives on the emerging literature attempting to link these two domains in ASC. Mikkelsen and colleagues (Mikkelsen et al., 2017) provide a comprehensive review of tactile processing ASC, with a focus on the inconsistencies observed in psychophysical studies of this sensory domain and mixed findings concerning linkages to social symptoms. The heterogeneity in participants and methods takes center stage in explaining these inconsistencies. Thye and colleagues (Thye et al., 2017) undertake an effort to reveal how, developmentally, a primary deficit in sensory processing could lead to social difficulties. They implicate a range of sensory processing deficits including visual, auditory, tactile, and olfaction/gustatory responses and link them, together with multisensory integration in a developmental model that proposes one way in which these deficits lead to social information processing deficits. Finally, Bolis and colleagues (Bolis and Schilbach, 2017) review and synthesize the sensory and social theories of ASC, then propose a theory of predictive coding that involves sensory/motor/social links and emphasizes the importance of optimal combination of sensory processing in the social and non-social domains for adaptive functioning.

Overall, these studies provide a wide variety of perspectives on the challenge of understanding how sensory and social processes interact in ASC. While many of the infant studies seem to emphasis the sensory aspects, the child and adult studies may place more weight on the social and top-down processes. There are two possible reasons for this contrast. One is that there could be a developmental change, with early difficulties in sensory processing leading to later social difficulties. However, the contrast could also arise from differences in the populations of participants in different studies. Research which focuses on infants, whether infant sibs or those with a genetic diagnosis such as fragile X, is seldom able to assess comorbid learning difficulties, and it is likely that many participants in autism infant-sibs studies have both autism and other learning difficulties. This makes it hard to determine if group differences are specific to autism or related to more general learning difficulties. In contrast, studies with older children and adults often include only participants with IQ scores in the normal range, providing a closer match between the ASC and neurotypical samples. This difference in the participant populations also makes it harder to compare results between infant studies and studies of older children or adults.

To gain a better understanding of the developmental time-course of both sensory and social difficulties in autism, it will be important to measure these factors in longitudinal studies which can track how different aspects of cognition in autism develop at different ages and interact. It will also be critical to gain a finer-grained understanding of heterogeneity within the autistic spectrum. Many studies reported here focus on only a small subset of those with autism, for example, those without learning difficulties who can complete the tests, or those with specific genetic differences (e.g. Fragile X) or those with an old sibling, who must be multiplex (more than one affected individual in a generation). There may be different genetic

and cognitive factors underlying autism in each of these groups, and it is important to take this into account in our current theories of autism spectrum conditions.

This special issue aimed to consider the question of whether social and sensory features of autism can be integrated. The papers do not provide a single answer to this question, but instead give us important insights into the relationship between sensory and social. The pattern of data suggests that ASC reflects a complex interplay of different difficulties at different stages of development. This may mean that a different factor altogether, such as motivational changes, must also be considered. Or it may mean that different individuals have different primary difficulties, which would be revealed by greater study of the heterogeneity of autism. The articles in this special issue offer only a sample of a burgeoning new area of investigation, one that will likely continue to thrive off from the many exciting questions raised by the articles presented here.

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