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Research report

The development of face orienting mechanisms in infants at-risk for autism

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HIGHLIGHTS

- Infants preferentially orient to socially relevant information such as faces.
- Infants at-risk for autism have a tendency to sustain attention to faces.
- Those infants who later develop autism show an equally strong face orienting response.
- Combined influence of social and attentional brain systems is implicated in autism.

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ABSTRACT

A popular idea related to early brain development in autism is that a lack of attention to, or interest in, social stimuli early in life interferes with the emergence of social brain networks mediating the typical development of socio-communicative skills. Compelling as it is, this developmental account has proved difficult to verify empirically because autism is typically diagnosed in toddlerhood, after this process of brain specialization is well underway. Using a prospective study, we directly tested the integrity of social orienting mechanisms in infants at-risk for autism by virtue of having an older diagnosed sibling. Contrary to previous accounts, infants who later develop autism exhibit a clear orienting response to faces that are embedded within an array of distractors. Nevertheless, infants at-risk for autism as a group, and irrespective of their subsequent outcomes, had a greater tendency to select and sustain attention to faces. This pattern suggests that interactions among multiple social and attentional brain systems over the first two years give rise to variable pathways in infants at-risk.

1. Introduction

In typical adults, social stimuli and contexts are processed by specialized neural systems including cortical and sub-cortical structures [2,41]. Further specialization within this "social brain" network has been described. For instance, parts of the fusiform cortex appear to be involved in detecting and identifying faces [31]. Sub-cortical structures like the superior colliculus and the amygdala play a role in orienting to faces and to relevant facial information (e.g. eyes) [3]. The orbitofrontal cortex has been associated with encoding the reward value of social stimuli [5]. The developmental basis of these patterns of cortical specialization remains the subject of debate [52,32]. One proposed model suggests that this cortical specialization for faces is partly a result of early biases to orient toward and attend to faces. Specifically, [37] proposed that a subcortical orienting system (which they termed "Conspec") initially biases the newborn to attend towards faces. This putative orienting system is driven by low-spatial frequency patterns characteristic of faces, and is sufficient to bias the input to developing cortical visual areas [38,39]. As a result of this biased input, alongside other constraints, over development some visual cortical areas become increasingly tuned to faces and related social stimuli. A manifestation of this functional specialization is the emergence of cortical tissue selectively activated by faces [40]. Based on this account we expect that infants' face processing abilities will be characterized by both very early biases and experience-dependent developmental changes.

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Partly motivated by such accounts of the emergence of the social brain in typical development, several groups have proposed that a lack of attention to, or interest in, social stimuli early in life may interfere with the emergence of developmental milestones that are critical for social learning, such as shared attention [13,20,38,39,60]. These cascading influences could preclude the typical development of socio-communicative, language and mentalizing skills, culminating in the behavioural presentation that characterises autism. Compelling as they are, the key elements of such developmental accounts have proved difficult to verify empirically.

Because a confirmed diagnosis of autism can only be made from around three years of age, most findings regarding preference for, or orienting to, various social and non-social stimuli have primarily been based on studies with older children and adults diagnosed with autism and have given rise to mixed findings. While some have suggested that face processing is the most informative model of the atypical development of the autistic brain [60], others have questioned whether difficulties in this area are universal [36]. Some of the inconsistencies have been attributed to possible changes over development in face orienting biases and face processing abilities (reviewed in [21]).

While no study has directly tested face orienting, several have documented difficulties in face processing in young children with autism, including recognition [10] and discrimination [12], as well as understanding of emotion [27] and eye gaze processing [9,38,39]. A few studies also documented atypical neural responses to faces in young children with autism [18,19,30]. These difficulties in childhood could be a result of reduced face expertise, in turn driven by an early impairment in face orienting. However, a few eye tracking studies draw a picture of emerging "disinterest" in faces during childhood. Assessment of children with autism at the age of two compared to those who are four-years-old suggests that relative to typically developing toddlers, toddlers with autism looked increasingly away from faces with age and attended atypically to key features of faces [10]. At four years of age, [1] also showed decreased attentional engagement to faces as measured by pupillary responses in children with autism relative to a control group. Atypical scanning and processing appear to be more pronounced in children relative to adults with autism, where findings are more mixed, suggesting the possibility that compensatory strategies may appear later in development (reviewed in [21,59]).

Notwithstanding these findings, other developmental models of autism have suggested that social orienting differences may not be the core deficits in autism, but instead that they originate from early general difficulties in controlling visual attention [6], which could, in turn, lead to problems in self-regulation as well as to a decrease in social orienting [43]. Because such deficits in visual attention are neither universal nor specific in autism, other researchers have proposed that an early specific deficit in orienting to socially relevant stimuli may be a necessary condition but probably not sufficient for autism to emerge. This deficit, however, would be compounded and amplified by the presence of visual attention difficulties [21]. Differences in social orienting would result in decreased input from socially relevant stimuli, while a problem with flexibly switching attention between different stimuli would result in 'locking' onto certain irrelevant aspects of the input (e.g. moving objects or, within the face, hairline instead of eyes). In support of this, one study which examined attentional disengagement from faces relative to objects found that toddlers with ASD disengaged visual attention from faces faster than developmentally delayed and typically developing toddlers [11]. These findings suggest that visual attention difficulties may also impair the acquisition of face processing skills.

As such, different hypotheses regarding the developmental origins and change in orienting to faces in autism are difficult to test in childhood once symptoms have become clearly expressed across multiple systems. Moreover, as described earlier, the human brain undergoes substantial development during the first years of life, with clear emergence and rapid change in social skill development in general and in face processing in particular. Indirect support for early differences in face orienting in autism come from retrospective studies looking back at the first two years of life using parental report or home videos. These studies show less orienting towards social stimuli and a reduced response to name calling from 9 months ([47,48]; Osterling et al., 2002; [64]) or younger [46] in children later diagnosed with autism, compared to those later diagnosed with developmental delay.

Against this background, a more recent approach has allowed for the prospective study of infants who are at increased risk for developing autism (for reviews see [24,66]). Later born siblings of children with autism are more likely to receive a diagnosis themselves as toddlers, relative to infants with no family history of autism. Interest in this group has been overwhelmingly driven by the search for 'early markers' as well as intermediate phenotypes, defined as autism-related characteristics observed in genetic relatives who do not have an autism diagnosis [24]. In other words, it is hoped that studying infant siblings may reveal the primary deficits in autism before symptoms are compounded by atypical interactions with the social and physical world, and before compensatory strategies and systems cloud the basic processing difficulties. Thus far, however, there has been little success in finding reliable markers for autism within the first year of life. On the one hand, infants below 12 months of age who are later diagnosed with autism show very few differences in the orienting to and scanning of faces when they interact with their caregiver [68] or with an experimenter [7,53]. By contrast, during the same period where infants at-risk show little behavioural difference from controls with no family history of autism [8,67], other studies using more direct measurements of brain activity have differentiated these groups in their response sensitivity to faces [22,23,50]. These early findings have motivated the view that understanding developmental changes in face orienting in infants at-risk as a group, and prior to the age of reliable diagnosis, will provide clues into variability in infants' responses to genetic risk [24]. Moreover, because the majority of face orienting studies with infants at-risk have relied on observing behaviour within the context of complex interactions and in the absence of non-social stimuli, it remains possible that a more structured observational setting may reveal more sensitive indicators of social and communicative characteristics in toddlerhood.

In the current study we tested a group of infants at-risk for autism and a control group of infants with no family history for autism on a 'face pop-out' task [28]. The infants were administered the task twice, first around 7 months and again around 14 months of age. In this task, infants are presented with arrays of a face along with four non-social stimuli, including a 'noise' stimulus generated from the same face within the array created to match its low-level visual properties [33]. Previous findings using a similar task design showed a pronounced face preference in 6-months-olds across a range of eye tracking measures and stimulus presentation contexts in typically developing infants [28]. A first measure, the direction of the first look, singled out faces over other non-face objects (the face 'pop-out' effect) and was not affected by face inversion, with both upright and inverted faces attracting infant's first looks above what was expected by chance. When looking time was analysed, faces again received more fixations than other objects but infants also looked longer at upright than inverted faces. It was concluded that orienting is driven by more general face properties (e.g. the particular low spatial frequencies of the face), which may act through both sub-cortical and cortical mechanisms [38,39]. Once on the face, and having access to more visual detail, face-specific cortical mechanisms ensure that the more prototypical upright