Research in Autism Spectrum Disorders 6 (2012) 842–851

Contents lists available at SciVerse ScienceDirect

Research in Autism Spectrum Disorders

Journal homepage: http://ees.elsevier.com/RASD/default.asp

Age trends in visual exploration of social and nonsocial information in children with autism

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ARTICLE INFO

Article history:
Received 18 November 2011
Accepted 21 November 2011

Keywords:
Autism
Attention
Visual exploration
Development
Eye tracking

ABSTRACT

Because previous studies of attention in autism spectrum disorders (ASD) have been restricted in age range examined, little is known about how these processes develop over the course of childhood. In this study we examined cross-sectional age effects on patterns of visual attention to social and nonsocial information in 43 typically developing children and 51 children with ASD ranging in age from 2 to 18. Results indicated a sharp increase in visual exploration with age and a decrease in perseverative and detail-focused attention for both groups of children. However, increased age was associated with greater increases in visual exploration for typically developing children than for those children with ASD. The developmental differences were most pronounced for attention to certain nonsocial stimuli as children with ASD demonstrated a disproportionate attentional bias for these stimuli from very early in life. Disproportionate visual attention to certain nonsocial objects relative to social stimuli in ASD spanned from early to late childhood, and thus may represent both an early and a persistent characteristic of the disorder.

1. Introduction

Children with autism spectrum disorders (ASD) preferentially orient to certain nonsocial information (Pierce, Conant, Hazin, Stoner, & Desmond, 2011; Sasson, Turner-Brown, Holtzclaw, Lam, & Bodfish, 2008) relative to social information (see also Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Extended experience with certain categories of information (i.e. nonsocial information) over time is likely to have effects on brain development and the specialization of dedicated neural circuitry (Gauthier, Skudlarski, Gore, & Anderson, 2000; Johnson, 2001). Thus, ASD may involve a difference in the balance of attention between social and nonsocial aspects of everyday experience which may over time manifest behaviorally as excessive nonsocial interests and behaviors coupled with diminished social interests and behaviors.

We recently developed a passive viewing eye-tracking task (the "Visual Exploration Task" VET) that can be used to measure the balance of attention between social and nonsocial information (Sasson et al., 2008). In a follow-up study we

Abbreviations: ASD, autism spectrum disorders; TD, typically developing; VET, visual exploration task; HAI, high autism interest; LAI, low autism interest; PIQ, performance intelligence quotient.

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doi:10.1016/j.rasd.2011.11.005

demonstrated that the VET could be easily administered to children of varying ages and cognitive abilities (Sasson, Elison, Turner-Brown, Dichter, & Bodfish, 2011). In the VET, a series of complex arrays containing images varying in categorical social and nonsocial content is presented and participants are permitted to explore each array in any manner they choose (i.e. there are no instructions). Eye-tracking technology is used to derive three discrete attentional variables that are conceptually linked to potential aspects of the autism phenotype: exploration (number of images fixated), perseveration (average fixation time per image explored), and detail-oriented visual scanning (number of discrete fixations per image explored).

Compared to children who are developing typically, children with ASD tend to explore fewer images overall, perseverate to a greater degree on the images they do explore, and are more detail-oriented in their inspection of individual images. Group differences are most pronounced for high-autism-interest (HAI) nonsocial images, a subcategory of nonsocial images that represent a diverse range of objects related to circumscribed interests as reported in South, Ozonoff, and McMahon (2005). Children with ASD disproportionally explored, perseverated and inspected in detail these object types relative to other image categories. This heightened salience of certain non-social aspects of the environment may have developmental repercussions, as the development of neural specialization related to many social information processing abilities are experience-dependant and may be adversely affected when the quantity and quality of visual experience with social stimuli is abnormal (Leppanen & Nelson, 2009; Sasson, 2006; Schultz, 2005).

In general, findings from the VET are consistent with other studies that have examined visual preferences in autism (Klin et al., 2009; Pierce et al., 2011), collectively suggesting that either social information is less salient, or that nonsocial information is more salient for young children with ASD. While these studies have established early abnormalities in visual attention as a robust cognitive phenotype in ASD, to date there have been no studies of visual attention in ASD that have examined age trends in attentional performance across a broad range of ages. Thus, it is currently unknown how these visual attention patterns change over time. An early bias toward nonsocial information could potentially canalize across development, thereby increasing the bias over time. Alternatively, the bias toward nonsocial information could attenuate over time due to accumulated exposure to the ubiquitous presence of social information encountered on a daily basis, particularly during the school-age years. Evidence supporting either of the hypotheses has the potential to elucidate optimal timing and the precise target for directed intervention.

The aim of the present study was to determine the effect of age on exploration, perseveration and detailed-oriented scanning during the VET in a cross-sectional sample of 2–18-year-old typically developing children and children with autism. We hypothesized that age would account for increases in visual exploration patterns as assessed by our three eye tracking measures in typically developing children, but that children with autism would show less of an age effect. To examine this question we (a) combined our two previous samples of participants from our existing VET studies (school-age from Sasson et al. (2008); preschool age from Sasson et al. (2011)), and (b) included new data from 20 additional participants in order to form a more complete age distribution spread proportionately from 2 to 18 years. Although this in part includes re-analysis of existing data, in neither of the previous studies was the age range sufficient to explore age trends. Thus the combined + new VET samples permitted a novel analysis aimed at an unexamined area of visual attention in ASD.

2. Methods

2.1. Participants

A total of 94 children participated in this study. Data from 74 of the 94 participants were drawn from two previous studies (Sasson et al., 2011; Sasson et al., 2008), while the remaining 20 are unique to the present study. The primary purpose of Sasson et al. (2008) and Sasson et al. (2011) was to examine categorical group differences in voluntary visual attention patterns between typically developing (TD) children and children with ASD. In contrast, the current study focuses on continuous age-related changes in attentional patterns, an approach that was only possible after combining across samples from both previous studies and including 20 new participants to complete a continuous distribution from 2 to 18 years of age. To achieve this distribution, a total of 31 additional participants were recruited, of which seven typically developing children (TD: all male; mean age: 175.42 months, SD: 14.73) and four children with ASD (all male; mean age: 143.50 months, SD: 29.01) were excluded because of missing or low quality data resulting from inaccurate eye tracking calibrations, or from non-compliance. Experimental procedures for the new participants were identical in all respects to those tested previously. The final sample of 94 children consisted of 51 with ASD (48 males, 3 females; mean age: 111.51 months (SD: 43.22); range: 32–207 months) and 43 who were TD (39 males, 4 females; mean age: 98.47 months (SD: 50.33); range: 25–194 months). The ASD and TD groups were not statistically different in sex $\chi^2 = 0.40$, $p = .53$ or age ($t(92) = -1.35$, $p = .18$), but PIQ did differ between groups for the 78 individuals (48 ASD, 30 TD) for which PIQ information was available ($t(76) = 4.50$, $p < .01$). Age and PIQ were not correlated ($r = .14$, $p = .22$). Demographic and clinical features of participants can be found in Table 1.

No participant had a history of seizure disorder, or any acute medical or genetic conditions. All had normal or corrected-to-normal vision. TD children were recruited through an message sent to UNC faculty and staff, and were excluded if they had a history of developmental or psychiatric disorder, were taking psychotropic medication, or had an immediate family with an ASD diagnosis. ASD children were recruited from the UNC Autism Research Registry in conjunction with regional TEACCH (Treatment and Education of Autistic and related Communication-handicapped CHildren) clinics. To be included in this registry, children are required to have a DSM-IV diagnosis of ASD, as determined by a licensed clinician with expertise in