Neuropsychologia 47 (2009) 248–257

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Eye-movements reveal attention to social information in autism spectrum disorder

S. Fletcher-Watson[a,*], S.R. Leekam[b], V. Benson[c], M.C. Frank[d], J.M. Findlay[b]

[a] Newcastle University, Sir James Spence Institute, Newcastle upon Tyne, UK
[b] Durham University, Department of Psychology, Durham, UK
[c] University of Southampton, School of Psychology, Southampton, UK
[d] Massachusetts Institute of Technology, Boston, MA, USA

ARTICLE INFO

Article history:
Received 4 June 2008
Received in revised form 2 July 2008
Accepted 17 July 2008
Available online 29 July 2008

Keywords:
Eye-tracking
Social attention
Scene viewing
Preferential-looking
Perception

ABSTRACT

Autism spectrum disorder (ASD) is a neurodevelopmental condition in which children show reduced attention to social aspects of the environment. However in adults with ASD, evidence for social attentional deficits is equivocal. One problem is that many paradigms present social information in an unrealistic, isolated way. This study presented adults and adolescents, with and without ASD, with a complex social scene alongside another, non-social scene, and measured eye-movements during a 3-s viewing period. Analyses first identified viewing time to different regions and then investigated some more complex issues. These were: the location of the very first fixation in a trial (indicating attentional priority); the effect of a task instruction on scan paths; the extent to which gaze-following was evident; and the degree to which participants' scan paths were influenced by the low-level properties of a scene. Results indicate a superficially normal attentional preference for social information in adults with ASD. However, more sensitive measures show that ASD does entail social attention problems across the lifespan, supporting accounts of the disorder which emphasise lifelong neurodevelopmental atypicalities. These subtle abnormalities may be sufficient to produce serious difficulties in real-life scenarios.

1. Introduction

The term autism spectrum disorder (ASD) refers to a set of neurodevelopmental disorders defined by atypicalities in three major symptom domains: communication, interaction and imagination (Wing & Gould, 1979). Children with ASD often show significant impairments in their attention to social elements of the environment. This includes well-documented impairments in triadic joint attention (Loveland & Landry, 1986; Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997; Leekam, Hunnisett, & Moore, 1998; Mundy & Newell, 2007; Mundy, Sigman, Ungerer, & Sherman, 1986) and attentional capture by social stimuli (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Dawson et al., 2004). Perhaps the most fundamental aspect of social attention is attention to another person, and this has also been shown to present problems for children with autism in both interactive (Leekam, Lopez, & Moore, 2000) and picture-viewing (Riby & Hancock, 2008) paradigms.

The prevalence of social attention problems in autism has led many to suggest that these may be at the root of the development of the disorder (Klin, Jones, Schultz, & Volkmar, 2003; Mundy & Neal, 2001; Schultz, 2005). These theories all suggest that autism results from an interaction between experience and neural development, creating developmental impairments in social behaviour and the 'social brain' (Brothers, 1990; Johnson, 2005). The amygdala is particularly important in the investigation of social attention, since abnormalities in this area are thought to be related to reduced fixation on the eye-region in autism (Corden, Chilvers & Skuse, 2008; Dalton et al., 2005) as well as underpinning wider deficits in social cognition (Baron-Cohen et al., 1999, 2000; Howard et al., 2000; Nacewicz et al., 2006).

Schultz (2005) suggests that early atypicalities in amygdala function (Dawson et al., 2002) contribute to the development of deficits in social behaviour as well as constraining neural development in regions such as the fusiform face area. This process would result in lifelong neural atypicalities, affecting the developmental trajectory of people with ASD, and maintaining the social problems characteristic of autism. This interpretation is supported by evidence of functional abnormalities in the brains of adults with ASD performing social cognitive tasks (Bird, Catmur, Silani, Frith, & Frith, 2006; Castelli, Frith, Happé, & Frith, 2002; Critchley et al., 2000;

* Corresponding author at: Newcastle University, Sir James Spence Institute, Royal Victoria Infirmary, Newcastle upon Tyne NE1 4LP, UK. Tel.: +44 191 202 3070; fax: +44 191 202 3095.
E-mail address: sue.fletcher-watson@ncl.ac.uk (S. Fletcher-Watson).

0028-3932/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2008.07.016

Freitag et al., 2008; Pelphrey, Morris, & McCarthy, 2005) and of structural abnormalities in the social brain (Frith, 2001; Kleinhans et al., 2008).

On the other hand, behavioural research shows that joint attention and social orienting is clearly related to developmental level and age in children (Leekam et al., 2000; Leekam & Ramsden, 2006; Mundy & Sigman, 1990; Mundy, Sigman, & Kasari, 1994). This raises the possibility that people with ASD (particularly high-functioning individuals) might be able to develop social skills not apparent in childhood, as they grow older. There has been very little investigation of attention to social information in adults with ASD and the question remains whether or not social attention continues to be impaired beyond childhood in autism.

One significant study to address this question employed eye-tracking technology to examine whether adults and adolescents with ASD looked at the same parts of a moving image with social content as typically developed (TD) adults (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). The authors found that people with ASD had atypical fixation patterns, looking less at the eye-region and more at the mouth and objects. However, others have suggested that this multi-sensory, moving stimulus produced group differences due to complex processing requirements, which particularly affected the performance of participants with ASD (Kemner & van Engeland, 2003). This suggestion is supported by evidence that children and adolescents with ASD only have abnormal fixation patterns for moving stimuli, which depict two people engaged in a social exchange (Speer, Cook, McMahon & Clark, 2007). The authors conclude that for static images or those which present social information in isolation (i.e. just one person) social attention is normal in autism.

Evidence from studies which present static images of isolated social information to adults with ASD remains equivocal. Some findings correspond with Speer et al., showing that fixation within a static face is normal in autism (Bar-Haim, Shulman, Lamy, & Reuveni, 2006). Others suggest that people with ASD do fixate less on the eye-region of faces specifically (Spezio, Adolphs, Hurley, & Piven, 2007), some that fixation to all central features of the face is reduced (Pelphrey et al., 2002). Moreover, all of these studies present only faces, without a visible body or realistic scene context, and so they tell us more about face processing (Sasson, 2006) than about attention to social information. One study that did present social information within a realistic scene showed a normal attentional bias for eye-gaze information in able young adults with autism (Fletcher-Watson, Leekam, Findlay, & Stanton, 2008). However, the 'change blindness' method used in this case could not reveal how attention is distributed temporally and spatially to the scene as a whole.

Research measuring the eye-movements of TD adults viewing social and non-social stimuli has recently demonstrated that they show a strong attentional preference for social scenes (Fletcher-Watson, Findlay, Leekam, & Benson, 2008). TD adults are capable of identifying human figures and even faces in peripheral vision and moving their eyes directly to that spot, with no delay in eye-movement processing time. This attentional preference to look at people is increased by the introduction of a task requirement to identify the gender of the person depicted. Furthermore, there is evidence of a gaze-following process, whereby the viewer looks at the person in the scene and subsequently to the area being fixated by that person.

Replicating this study with participants with ASD can help to reveal whether they will also preferentially attend to and prioritise social information. Given the equivocal nature of existing evidence, it is hard to make concrete predictions. If stimulus complexity makes a difference to adults' attention, our static stimuli, which depict only one person, might not produce atypical fixation patterns in participants with ASD, in line with findings in children (Speer et al., 2007). On the other hand, by presenting realistic social information in a naturalistic context, our experimental stimuli could produce larger group differences than have been found in experiments using isolated face stimuli, such as that by Pelphrey and colleagues (2002). Of particular interest will be the degree to which each group fixates on the eye-region of the person depicted—a measure perhaps directly related to amygdala function (Dalton et al., 2005) and to social function (Klin et al., 2002).

In addition, we will investigate three further questions of interest for autism research. First, an examination of the effect of a task instruction on social attention will help to reveal the possible distinction between what someone with ASD does spontaneously, and what they can do when instructed. Second, the presence of gaze-following behaviours when viewing a static visual scene will be investigated. Third, we will assess the degree to which low-level stimulus properties direct visual fixation. This latter question is of particular interest in the context of an ongoing debate about the relative influence of low and high-level stimulus properties on attention in TD individuals (Hayhoe & Ballard, 2005).

Finally, some research suggests that people with ASD show atypical saccades and other types of eye-movement (Kemner, Verbaten, Cuperus, Camfferman, & Van Engeland, 1998; Minshew, Luna, & Sweeney, 1999; Rosenhall, Johansson, & Gillberg, 1988; Takrae, Minshew, Luna, Krisky, & Sweeney, 2004; Takrae, Minshew, Luna, & Sweeney, 2004). Therefore, an initial comparison of the two participant groups in this study will also look for differences in basic eye-movement patterns.

Table 1
Descriptive statistics for each group, with *t*-test results for group comparisons

	ASD		TD		*t*-Test result
	Mean	S.D.	Mean	S.D.	
Age (years)	18.8	2.3	21.5	7.8	$t(25) = 1.19$, $p = .24$
FSIQ	91.3	12.7	107.1	13.5	$t(25) = 3.06$, $p = .005$
VIQ	87.2	12.3	104.5	13.0	$t(25) = 3.53$, $p = .002$
PIQ	97.3	15.9	108.7	13.5	$t(25) = 2.02$, $p = .054$

2. Method

2.1. Participants

The TD group comprised 15 adolescents and adults (2 female) aged 17–48 years, from mainstream high schools and further education colleges in the Durham area. None of these participants had taken part in previous research with this paradigm. Participants completed the Autism Quotient questionnaire to rule-out autistic spectrum diagnosis (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001) and all received a score well below the recommended cut-off of 32+ for ASD (TD range 10–25).

The ASD group comprised 12 adolescents and adults (2 female) aged 16–23 years, with high-functioning autism or Asperger's syndrome. All these participants attended a specialist college in the Sunderland area for which a diagnosis of autism or Asperger's syndrome was a criterion of admission. All had been diagnosed by experienced clinicians (a psychiatrist or clinical psychologist employed by the National Health Service) working in specialised centres, as meeting DSM-IV criteria for either high-functioning autism or AS (American Psychiatric Association, 1994). These diagnoses were confirmed, upon each participant's admission to the college, by a second clinical psychologist.

The groups were group-wise matched on chronological age, rather than using one-to-one matching, since age in an adolescent and adult group is not likely to affect eye-movements or attentional preference. The full Wechsler abbreviated Scales of Intelligence (WASI) was administered to all participants (Wechsler, 1999). While the groups were comparable in terms of educational level, it was not possible to match them on IQ. There were significant group differences in full-scale IQ, verbal IQ and performance IQ. IQ scores were therefore included as covariates if there was evidence of a significant correlation with dependent variables (Keppel & Zedeck, 1989). Descriptive statistics and *t*-test results for group differences are illustrated in Table 1.