Vision Research 121 (2016) 85–94

Contents lists available at ScienceDirect

Vision Research

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

No difference in cross-modal attention or sensory discrimination thresholds in autism and matched controls

Sarah M. Haigh [a,*], David J. Heeger [b], Laurie M. Heller [a], Akshat Gupta [a], Ilan Dinstein [c], Nancy J. Minshew [d], Marlene Behrmann [a]

[a] Department of Psychology and Center for the Neural Basis of Cognition, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA
[b] Department of Psychology and Center for Neural Science, New York University, 6 Washington Place, New York, NY 10003, USA
[c] Psychology Department, Ben-Gurion University of the Negev, 653, Beer-Sheva 84105, Israel
[d] Departments of Psychiatry & Neurology, University of Pittsburgh, Pittsburgh, PA 15213, USA

ARTICLE INFO

Article history:
Received 7 October 2015
Received in revised form 2 February 2016
Accepted 22 February 2016
Available online 1 March 2016

Keywords:
Autism
Vision
Audition
Attention

ABSTRACT

Autism has been associated with abnormalities in sensory and attentional processing. Here, we assessed these processes independently in the visual and auditory domains using a visual contrast-discrimination task and an auditory modulation-depth discrimination task. To evaluate changes in sensory function by attention, we measured behavioral performance (discrimination accuracy) when subjects were cued to attend and respond to the same stimulus (frequent valid cue) or cued to attend to one stimulus and respond to the non-cued stimulus (infrequent invalid cue). The stimuli were presented at threshold to ensure equal difficulty across participants and groups. Results from fifteen high-functioning adult individuals with autism and fifteen matched controls revealed no significant differences in visual or auditory discrimination thresholds across groups. Furthermore, attention robustly modulated performance accuracy (performance was better for valid than invalid cues) in both sensory modalities and to an equivalent extent in both groups. In conclusion, when using this well-controlled method, we found no evidence of atypical sensory function or atypical attentional modulation in a group of high functioning individuals with clear autism symptomatology.

1. Introduction

Autism is characterized by a range of atypical behaviors including sensory hypo- and/or hyper-sensitivities (Diagnostic and Statistical Manual 5th edition, DSM-5). One possible explanation is that alterations in sensory sensitivities may be due to abnormal attentional processes, which may cause individuals with autism to become overly fixated on a stimulus (Baron-Cohen, Ashwin, Ashwin, Tavassoli, & Chakrabarti, 2009; Liss, Saulnier, Fein, & Kinsbourne, 2006) or easily distracted by other stimuli (Burack, 1994; Murphy, Foxe, Peters, & Molholm, 2014). Alternatively, altered sensory sensitivities may be the product of intrinsic differences in the function of the sensory systems themselves (Meilleur, Berthiaume, Bertone, & Mottron, 2014), for example, altered signal-to-noise ratios in sensory signals (Rubenstein & Merzenich, 2003; Milne, 2011; Dinstein et al., 2012; Haigh, Heeger, Dinstein, Minshew, & Behrmann, 2014), and may be independent of attention. Whilst sensory and attentional processing are closely related, equating individual differences in one domain may illuminate deficits related to the other.

While some studies have reported that individuals with autism exhibit higher sensory thresholds than controls in discrimination of visual (Milne et al., 2002), auditory (Erviti et al., 2015) and somatosensory (Puts, Wodka, Tommerdahl, Mostofsky, & Edden, 2014) stimuli, others have reported no significant differences across groups (Cascio et al., 2008; O'Riordan & Passetti, 2006), or even lower (i.e. better) sensory thresholds than controls (Blakemore et al., 2006; Fan, Chen, Chen, Decety, & Cheng, 2013). This apparent discrepancy emphasizes the need to control for any individual differences in sensory thresholds when measuring attention to sensory stimuli. For example, individuals with migraine generally show impaired performance on motion detection tasks (McKendrick & Badcock, 2004; McKendrick, Vingrys, Badcock, & Heywood, 2001; Antal et al., 2005; Ditchfield, Mckendrick, & Badcock, 2006; Shepherd, 2006). However, contrast sensitivity was also found to be abnormal in migraine, and

* Corresponding author at: Clinical Neurophysiology Research Laboratory, Department of Psychiatry, School of Medicine, University of Pittsburgh and UPMC, Suite 420 Oxford Building, 3501 Forbes Avenue, Pittsburgh, PA 15212, USA.
E-mail address: haighsm@upmc.edu (S.M. Haigh).

http://dx.doi.org/10.1016/j.visres.2016.02.001
0042-6989/

mediated performance on motion tasks (Shepherd, Beaumont, & Hine, 2012), highlighting the effect of early sensory processing on more complex sensory tasks.

Attributing atypical sensory sensitivities to differences in attention in autism may constitute an appealing account. However, the evidence for deficits in attention in autism is mixed, partly confounded by the variability across studies in the attentional processes tested. Several studies, mostly conducted with children with autism, have observed impairments in dividing attention between stimuli (Belmonte, Gomot, & Baron-Cohen, 2010), and sustaining attention (Schatz, Weimer, & Trauner, 2002), similar to that seen in individuals with Attention Deficit Hyperactivity Disorder (ADHD) (Corbett & Constantine, 2006). Additionally, deficits in shifting attention have been documented in autism (Wainwright & Bryson, 1996; Wainwright-Sharp & Bryson, 1993; Williams, Goldstein, & Minshew, 2013), and the difficulty in switching was exaggerated when participants were required to switch between stimuli from different sensory modalities compared to a single modality (Reed & McCarthy, 2012).

In contrast to the evidence described above, other studies have reported no differences in attentional processing between adults with autism and controls. The majority of these studies used highly controlled psychophysical methods to isolate attention, and found that exogenous and endogenous attention cues robustly modulated visual discriminability to the same extent in both autism and control groups across several different tasks (Grubb et al., 2013a, 2013b). Renner, Grofer Klinger, and Klinger (2006) also found no significant difference in endogenous attention, but found impaired exogenous attention in children with autism. No significant reductions in accuracy or reaction time measures to a selective attention task were also reported in adults with autism regardless of the number of distractors (Remington, Swettenham, Campbell, & Coleman, 2009). Ciesielski, Knight, Prince, Harris, and Handmaker (1995) also found no evidence for behavioral differences in focused auditory and visual tasks, or in divided auditory and visual tasks, but did note that attentional modulation of event-related potentials (ERPs) was significantly weaker in individuals with autism. Furthermore, several studies have even reported stronger attentional modulation in autism than controls (Oades, Walker, Geffen, & Stern, 1988), leading to superiority in visual search, which is less affected by the presence of distractors (Kaldy, Giserman, Carter, & Blaser, 2013; Ohta et al., 2012; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; but see Grubb et al., 2013a, 2013b). Some have attributed the superior visual search capabilities in autism to attentional, rather than sensory, processes (Happé & Frith, 2006; Kaldy et al., 2013), because visual search performance did not reliably correlate with enhanced perceptual discrimination (Brock, Xu, & Brooks, 2011). Others have argued that altered sensitivity to sensory stimuli can lead to increased attention to detail (Robertson, Kravitz, Freyberg, Baron-Cohen, & Baker, 2013a, 2013b, 2014; Baron-Cohen et al., 2009; Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009; Mottron, Dawson, & Soulières, 2009).

A possible source of the discrepancy in the literature is the multitude of methodologies used to measure perception and attention, some being better at controlling for possible confounding variables than others (Ames & Fletcher-Watson, 2010). Tasks that only measure reaction times and not accuracy (Williams et al., 2012; Wainwright & Bryson, 1996; Wainwright-Sharp & Byson, 1993) can lead to ambiguous results: differences in reaction time could reflect differences in either speed of processing, discriminability, or selection criteria. In addition, they could reflect speed-accuracy trade-offs (see, for example, Carrasco & McElree, 2001). In the current study, we adjusted the task to compensate for individual differences in sensory processing, and measured both accuracy and reaction time.

In addition, a key challenge in determining whether the atypicalities in autism derive from differences in sensory or attentional processing results from the fact that investigating sensory processing often involves a task in which attention is directed (i) toward a stimulus to measure the effects of actively processing sensory stimuli, or (ii) away from the stimulus to ensure that sensory stimuli are perceived passively by engaging participants in a separate task. In either case, an attentional manipulation is involved when evaluating sensory processing.

We adopted an approach to evaluate both sensory processing and its modulation by attention in an attempt to parse the effects of sensory processing on attention modulation in autism and controls. We initially examined sensory processing to ascertain differences in visual and auditory thresholds between the two groups. We then probed sensory processing with and without engaging additional attentional demands. The attention task required switching attention between sensory modalities to keep the two channels of sensory information as separate as possible. Attending to one sensory modality or the other ensured that the stimuli were exactly the same across valid and invalid trials, and that only the cue changed. In addition, a measure of sensory sensitivity was collected using the Glasgow Sensory Questionnaire (Robertson & Simmons, 2013). Responses on the questionnaire were compared with discrimination thresholds to assess whether greater self-reported sensitivity were correlated with improved discrimination thresholds. Clinical measures (for example, the ADOS scores for the individuals with autism) were also compared with attention measures and discrimination thresholds to test whether individuals with higher symptomatology also performed more poorly on the attention task and/or on discrimination performance.

In the first sensory experiment, we measured visual contrast-discrimination thresholds to sinusoidal gratings while, in the second, we measured auditory modulation-depth discrimination thresholds. If autism is associated with poor sensory processing, one would expect thresholds to be higher in the autism group. In the attention experiment, we measured discrimination performance while the same visual and auditory stimuli were presented concurrently at the participant's previously determined threshold level. In 75% of the trials, participants were cued to attend and respond to the same stimulus (valid cue), and, in the remaining trials, participants were cued to attend to one stimulus but respond to the non-cued stimulus (invalid cue). This made it advantageous for participants to pay attention to the cues and enabled us to compare the effects of attention on discrimination accuracy (Carrasco, 2011). If autism is associated with abnormal attentional processing, then attentional modulation of discrimination accuracy in valid versus invalid cued trials would be weaker in individuals with autism compared to controls.

2. Materials and methods

2.1. Participants

Thirteen males and two females (mean age 27 years; range 21–42) diagnosed with autism and no other identifiable etiology, including ADHD, consented to participate. Screening tests to determine eligibility of the participants with autism included the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), the Kaufman Test of Educational Achievement (K-TEA) (Kaufman & Kaufman, 1985), the Autism Diagnostic Observation Schedule General (ADOS-G; Lord et al., 2000), and the Autism Diagnostic Interview Revised (ADI-R; Le Couteur et al., 1989; Lord, Rutter, & Le Couteur, 1994). The diagnosis of autism, provided by the two structured instruments, was confirmed by expert clinical opinion (Dr. Nancy Minshew). Participants with autism were also required