Research in Autism Spectrum Disorders 7 (2013) 1250–1256

Contents lists available at ScienceDirect

Research in Autism Spectrum Disorders

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

Can gaze-cueing be helpful for detecting sound in autism spectrum disorder?

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ARTICLE INFO

Article history:
Received 16 April 2013
Received in revised form 28 June 2013
Accepted 1 July 2013

Keywords:
Auditory
Autism spectrum disorder
Cross-modal
Gaze
Joint attention

ABSTRACT

Autism spectrum disorder (ASD) is a developmental disorder characterized by impaired social interaction, including joint attention, but psychological studies generally have reported intact gaze-triggered joint attention in ASD. These studies used a uni-modal paradigm (i.e. visual cue–target pairs) with eyes or faces as cues and letters or dots as targets. However, it has not been determined whether joint attention is impaired under cross-modal conditions in ASD, although cross-modal impairment has been reported. This study investigated joint attention in ASD under cross-modal conditions with gaze stimuli as visual cues and two kinds of sound (social voice or non-social tone) stimuli as targets. The task for the subject was to locate the target sound and click as soon and as accurately as possible. The ASD group was impaired in joint attention when a tone was used as the target, while both groups showed joint attention to a voice. The results suggest that cross-modal joint attention is impaired in the ASD group when the cue–target relationship is weak (i.e. social cue and non-social target) while it is unimpaired when there is a strong cue–target relationship (i.e. social cue and social target).

1. Introduction

By following others people's eye gaze, we can recognize their focus of attention. The ability to coordinate attention to an object or event with others is a phenomenon called joint attention (Mundy, Sigman, Ungerer, & Sherman, 1986). Although joint attention is thought to be built upon basic neural mechanisms detecting the gaze direction, it also extends to understanding pointing or other social cues by the interactive partner or sharing an awareness of the object or event with the partner; therefore, it is considered to be a uniquely human ability underlying social communication. It is widely known that people attend to each other (by eye contact, smiling, mimicking facial expressions and gestures etc.) to augment shared understanding, and it plays a crucial role in verbal communication. Joint attention is important for at least two reasons: (1) it allows us to learn about the other person's inner state (such as interest, emotion and intentions), (2) it informs us about what the speaker is talking about and where the object of interest is in the environment.

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http://dx.doi.org/10.1016/j.rasd.2013.07.001

Autism spectrum disorders (ASD), including autistic and Asperger's disorders, are characterized by qualitative impairments in social interaction (American Psychiatric Association [APA], 2000). One of the important features of these social impairments is thought to be a deficit of joint attention (APA, 2000; Mundy et al., 1986). A lack of joint attention has been well documented in the clinical literature and recently it has drawn attention as an early marker of ASD (APA, 2000); however, contrary to the clinical findings, experimental studies generally have reported intact joint attention in ASD (Chawarska, Klin, & Volkmar, 2003; Kylliäinen & Hietanen, 2004; Rutherford & Krysko, 2008; Senju, Tojo, Dairoku, & Hasegawa, 2004; Swettenham, Condie, Campbell, Milne & Coleman, 2003; Vlamings, Stauder, van Son, & Mottron, 2005; see Nation & Penny, 2008 for review). These studies applied Posner's cueing paradigm (Posner, 1980), in which uni-modal (i.e. visual) cue–target pairs were used. In the paradigm, subjects first saw a gaze cue (directed toward right or left), followed by a target, a dot or a letter, which appeared either on the right or left of the display screen. The subjects were asked to locate the target and respond as quickly and accurately as possible, and the reaction time (RT) was measured. Most of the previous studies observed that individuals with ASD, as well as typically developing subjects, responded faster when targets appeared in the same direction as gaze cues than when they appeared in the opposite direction. These results indicate intact joint attention in ASD.

To investigate gaze-triggered joint attention in ASD, previous studies have used visual cues and targets; however, in real life, there are various environmental stimuli, such as sounds and objects. We constantly need to use joint and shared attention with others by recognizing cues and targets that belong to different modalities; therefore, it is important to investigate the effect of joint attention under cross-modal conditions. Previous studies have examined joint attention in typically developing individuals under cross-modal conditions (Borjon, Shepherd, Todorov, & Ghazanfar, 2010; Newport & Howarth, 2009). Both studies presented visual cues and auditory targets and showed significant gaze-triggered joint attention under cross-modal conditions, as in a uni-modal paradigm. Based on the finding that cross-modal processing, such as attention-switching (Reed & McCarthy, 2011) and audio–visual integration (Charbonneau et al., 2013), was impaired in children with ASD and that social communication has a cross-modal aspect in many circumstances, it is speculated that individuals with ASD may fail to show joint attention under cross-modal conditions.

Previous studies have reported orientation to auditory stimuli, social voice and non-social tone in ASD. Individuals with ASD showed poor responses to social (i.e., calling the child's name) compared with non-social (i.e., phone ringing) stimuli in 3–4-year-old children with ASD (Dawson et al., 2004). Furthermore, atypical activation in response to social sounds in adult ASD was also observed when participants were requested to simply distinguish sounds of voice and tone (Čeponienė et al., 2003; Gervais et al., 2004; Whitehouse & Bishop, 2008), although another study did not suggest impairment of the auditory cortex while listening to sounds intentionally (i.e., voice, tone or story) (Funabiki, Murai, & Toichi, 2012). Based on these findings, we manipulated social (voice) and non-social (tone) sounds to examine cross-modal joint attention without any hypothesis about the impairment of gaze-triggered attention to a specific target.

In the present study, we examined joint attention under visual–auditory cross-modal conditions in individuals with high-functioning ASD and age-matched typically developing controls. In addition, we manipulated two sounds as targets, i.e. social voice and non-social tone, to refer the relationship between the cue and target. The subjects were first presented with a neutral eye gaze as a cue and subsequently asked to identify the direction of the subsequent auditory target as accurately and rapidly as possible. The aims of the study were: (1) to investigate whether visual–auditory cross-modal joint attention is impaired in ASD and (2) to examine whether cross-modal joint attention is affected by the type of auditory target in ASD.

2. Materials and methods

2.1. Ethics statement

All subjects older than 18 years of age and the parents of those younger than 18 years of age gave written informed consent to participate in this study, the principle of which was applied to the participants in the ASD group since they all had normal IQ. This study was approved by the local ethics committee of Kyoto University Graduate School and Faculty of Medicine.

2.2. Participants

Eighteen individuals with ASD and 20 controls participated in this study. The ASD and control groups were matched for chronological age (ASD group: M = 25.6, SD = 8.9; Control: M = 22.6, SD = 4.1, independent t-test, $t(36) = 1.34$, $p = 0.189$) and gender (13 men and 7 women in the control group and 15 men and 3 women in the ASD group, Fisher's exact test, $p = 0.278$). All of the controls were recruited from Kyoto University students. The verbal and performance IQ in the ASD group was measured using the Japanese version of the Wechsler Adult Intelligence Scale – revised (Shinagawa 1990) or the Wechsler Intelligence Scale for Children – revised (Kodama 1982). The IQs of all participants in the ASD group were in the normal range (full-scale IQ: M = 109.2, SD = 17.4; verbal IQ: M = 108.1, SD = 20.4; performance IQ: M = 106.9, SD = 14.4). All subjects were right-handed, as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971), and had normal or corrected-to-normal visual and auditory acuity.

Fourteen of the ASD group had been diagnosed with Asperger's disorder, and four with pervasive developmental disorder not otherwise specified (PDD-NOS) by two child psychiatrists using DSM-IV-TR (APA, 2000). The diagnosis was based on an