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"*The archeologist's career ended in ruins*": Hemispheric differences in pun comprehension in autism

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ABSTRACT

Appropriate interpretation of figurative language involves inferring the speaker's intent by integrating word meaning with context. In disorders like autism, understanding intended and contextual meanings in language may pose a challenge. Such difficulties are prevalent even when individuals exhibit otherwise fluent language ability (Szatmari et al., 1990). A pun is a rhetorical technique in which a speaker deliberately invokes multiple meanings through a word or phrase likely resulting in a joke. Comprehending puns may involve identifying multiple meanings of a word, embedding it in right contexts, and understanding the underlying humor. This fMRI study investigated the brain responses associated with figures of speech like puns. In the fMRI scanner, participants read sentences containing puns (e.g. *To write with a broken pencil is pointless*) and control sentences (literal meaning) presented in a blocked design format. The participants' task was to silently read and understand one meaning (in the literal condition) or two meanings (in the pun condition). Participants with autism, relative to typical controls, showed an increase in overall activation while comprehending sentences containing puns, particularly within the right hemisphere as well as in relatively posterior brain areas. Overall, there was reduced response in left hemisphere areas, reduced response to humor, and more distributed recruitment of regions in autism relative to control participants. We also examined the relationship between symptom severity in autism and verbal ability with brain responses to pun comprehension finding negative and positive correlations respectively. Overall, the results from the present study suggest that individuals with autism resort to altered neural routes in comprehending language in general, and figurative language in particular.

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Introduction

Impairment in language and communication has been featured as one of the defining characteristics of autism spectrum disorders (ASD). Previous research has examined anatomical (Herbert et al., 2002, 2004, 2005) as well as functional brain abnormalities in autism. Altered neural processing has been reported in concrete and abstract word comprehension (Harris and Moreno, 2006), sentence comprehension (Just et al., 2004; Kana et al., 2006), narrative comprehension (Mason et al., 2008), orienting to the *speechness* quality of sounds (Ceponiene et al., 2003), and comprehending prosody (Wang et al., 2006). While morphometric studies have found reversed asymmetry (larger right hemisphere regions) of the language association cortex in autism (Abell et al., 1999; Foundas et al., 1998; Herbert et al., 2002, 2004, 2005; Muller et al., 1998), functional studies have suggested increased recruitment of right hemisphere regions in higher level language tasks (Mason et al., 2008; Muller et al., 1998; Takeuchi et al., 2004; Wang et al., 2006). These findings suggest that people with autism may rely on alternate and compensatory neural routes to accomplish complex linguistic tasks (Baron-Cohen et al., 2001). Despite global difficulties in processing language, the deficits in language comprehension in autism have been particularly pronounced in the social and communicative domains.

A large portion of the information that we need in order to accurately understand language is not directly stated or written (Dennis et al., 2001). Instead, the listener makes inferences regarding the speaker's intent in order to comprehend the meaning. While comprehending figurative speech, which is intended to go beyond the literal meaning, the listener usually has to infer the speaker's intent in order to arrive at the meaning (Johnson-Laird, 1983; Whitney et al., 1991). This ability is a critical component of social communication, an area where individuals with autism have been shown to have a deficit (Baltaxe and Simmons, 1977; Tager-Flusberg, 1993; Tager-Flusberg, 1996; Tager-Flusberg and Anderson, 1991) even if they exhibit fluent language ability (Szatmari et al., 1990). A few behavioral studies have documented the problems individuals with autism face in figurative language comprehension (Dennis et al., 2001; Gold et al., 2010; Happe, 1993; Norbury, 2005; Tager-Flusberg, 1995).

Inferring the speaker's intent in figures of speech may also involve integrating word meaning with appropriate context. Perhaps the first

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line of evidence pertaining to impairments in context integration in autism comes from the study of homographs (Happe, 1994, 1997; Snowling and Frith, 1986). These studies examined the pronunciation of homographs (e.g., there was a *tear* in her eye; there was a *tear* in her dress) and found that the presence of contextual information did not help participants with autism in processing information for context-dependent meaning. A relatively recent study (Dennis et al., 2001) examining idiom comprehension found that although high-functioning individuals with autism were able to define words, identify multiple meanings of ambiguous words, and understand mental state verbs, they exhibited significant difficulty inferring the meaning of these verbs when placed in context. Nevertheless, results from current research have not been entirely consistent, leading to debate over the source of these difficulties and the degree to which they can be generalized. For example, Norbury (2005) found that individuals with autism with normal level core language abilities were able to perform similarly to typically developing peers in terms of utilizing contextual cues and suppressing irrelevant information to understand ambiguous phrases. However, individuals with core language impairment, either on the spectrum or not, exhibited difficulties with integration of context. Therefore, it is possible that language difficulties itself may drive this deficit, independent of ASD diagnosis. Although only a few studies have examined the behavioral aspects of figurative language comprehension in autism, even fewer have investigated the neural bases. A recent EEG study (Gold et al., 2010) found increased difficulty for the participants with autism on both novel and conventional metaphor tasks as opposed to typically developing controls. The results of another study of semantic judgment involving metaphors in autism (Gold and Faust, 2010) indicated significantly less right hemisphere activation for the autism group during novel metaphor comprehension tasks than that which was found in controls. Other neuroimaging studies examining discourse processing (Mason et al., 2008), and communicative intent (Wang et al., 2006) found increased right hemisphere activation in individuals with autism. The discrepancy in activation results between these studies could either be the result of differences between the types of language tasks assessed or due to the differences within the individuals with autism comprising the groups.

Although there have been previous neuroimaging studies investigating comprehension of metaphor (Gold et al., 2010), irony (Wang et al., 2006), narrative (Mason et al., 2008), and ambiguity (Braeutigam et al., 2008; Diehl et al., 2008) in autism, to our knowledge, no study has yet examined the brain response to comprehending puns. A pun is a specific type of figurative speech that an individual deliberately uses to invoke more than one meaning from a single word or phrase (Coulson and Severens, 2007). Puns are commonly humorous in nature due to the multiple meanings implied. In an EEG study of pun comprehension in typically developing individuals, Coulson and Severens (2007) found that initially both the relevant and implied meanings of the pun word were active in the left hemisphere but only the most relevant meaning was active in the right hemisphere. However, following a 500 ms delay, both meanings were activated in both hemispheres. Nevertheless, it is important to note the heterogeneity of puns and, as such, that it is unlikely that their comprehension is subserved by one central "pun comprehension network." Although both puns and narrative jokes may rely on integration of word meanings with context, the focus of understanding puns is to recognize the multiple meanings of the pun word.

The primary goal of the current study is to examine the brain responses associated with comprehending sentences involving pun in high-functioning adults with autism and in typically developing control participants. We predicted that participants may recruit different neural routes, relative to typical controls, in comprehending pun. Prior research has indicated that complex language tasks show increased recruitment of right hemisphere brain regions (Heiss et al., 1997; Just et al., 1996) and greater recruitment of relatively posterior language regions, such as Wernicke's area in autism (Harris et al., 2006; Just et al., 2004; St George et al., 1999). In addition, participants with autism may not appreciate the humor in puns. If this is the case, we predicted that they would show decreased activation in middle and superior frontal regions, previously found to be involved in humor and laughter (Shammi and Stuss, 1999).

Research examining the neural basis of autism has mainly resulted in mixed findings, and those examining language have been no exception. Recently there has been an attempt in the literature to analyze such findings, often by attempting to disentangle both specific and non-specific factors in autism (Mottron, 2004). Such inconsistency is thought to result from heterogeneity among individuals with autism spectrum disorders (Stanfield et al., 2008). While individuals with autism were often thought to be fairly homogeneous in terms of intellectual ability, they actually represent a wide range of cognitive abilities. In fact, high-functioning individuals with autism are now thought to display the same variability in terms of average intelligence as typically developing individuals (Mottron, 2004). Due to such wide variability, IQ has become a potential target for distinguishing the effect of autism-specific characteristics from external sources of heterogeneity. One aspect of intellectual ability that may be particularly relevant to the current study is verbal ability or verbal IQ (VIQ). Verbal intelligence refers to the ability to solve problems and analyze information using language based reasoning skills, and recent evidence suggests that individuals with autism often have a wide range of VIQ scores on standardized measures (Charman et al., 2011). In addition to external or non-specific factors, inconsistencies in past results may also be due to variability within symptomatology of the disorder. More specifically, the variability in the severity of autism symptoms among participants may blur study results. Therefore, this study also examined the relationship between VIQ, autism severity, and brain response data to learn more about the heterogeneity among participants and its influence on cognitive strategies and neural routes used in accomplishing a task.

Materials and method

Participants

Sixteen high-functioning young adults with autism and 16 age and IQ-matched typical control participants took part in the current fMRI study (age range: 16 to 35 years; minimum Full Scale and Verbal IQ: 80, measured using the Wechsler Abbreviated Scales of Intelligence). Participants with autism were recruited through the databases of the Civitan-Sparks Clinic at University of Alabama, Birmingham (UAB) and the Autism Spectrum Disorders Clinic, University of Alabama, Tuscaloosa. All participants had previous diagnoses of an ASD. In addition, diagnoses were confirmed on the basis of the Autism Diagnostic Interview—Revised (ADI-R) or the Autism Diagnostic Observation Schedule—Generic (ADOS-G) (Lord et al., 1994) and clinical impressions for all participants. Since most participants received ADI-R diagnoses, which are based on symptoms across the lifetime, current ASD symptoms were assessed using the Social Responsiveness Scale (SRS) (Constantino et al., 2003). The average SRS scores for the 14 participants with ASD whose parents participated was 81.00 (SD = 30.84) which falls within the mild to moderate range of symptom severity. Control participants were recruited using flyers and advertisements on the UAB campus as well as through the UAB Psychology Department's *Introduction to Psychology* (PY101) course. All participants included in the study were male, right-handed, and native English speakers. Participants were not included in the study if they indicated having worked with metal or having metal implanted in their bodies (either surgically or accidentally) or if they had a history of psychiatric disorders. None of the participants indicated having a cognitive disorder, anxiety disorder, schizophrenia, or obsessive compulsive disorder. Forty participants (all native English speakers) were