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Visual and linguistic narrative comprehension in autism spectrum disorders: Neural evidence for modality-independent impairments

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ABSTRACT

Individuals with autism spectrum disorders (ASD) have notable language difficulties, including with understanding narratives. However, most narrative comprehension studies have used written or spoken narratives, making it unclear whether narrative difficulties stem from language impairments or more global impairments in the kinds of general cognitive processes (such as understanding meaning and structural sequencing) that are involved in narrative comprehension. Using event-related potentials (ERPs), we directly compared semantic comprehension of linguistic narratives (short sentences) and visual narratives (comic panels) in adults with ASD and typically-developing (TD) adults. Compared to the TD group, the ASD group showed reduced N400 effects for both linguistic and visual narratives, suggesting comprehension impairments for both types of narratives and thereby implicating a more domain-general impairment. Based on these results, we propose that individuals with ASD use a more bottom-up style of processing during narrative comprehension.

1. Introduction

The ability to understand sequential events is thought to be unique, even fundamental, to the human condition. The comprehension of narrative sequences is central to school, work, and everyday life, but poses significant challenges for individuals with communication and neurodevelopmental disorders like autism. This study explores whether such comprehension deficits in individuals with autism are language-specific or represent global difficulties with understanding narrative sequences.

Narrative theory has a long history in philosophy, literature, and psychology, with many different specific definitions of what constitutes a narrative (e.g. Bruner, 1991, 1997; Richardson, 2000; Walsh, 2007). For the purposes of the current study, we conceptualize "narrative" or a "story" according to several characteristics included in many of these definitions: a narrative consists of an actor or actors with goals and motivations (Bruner, 1997) and a temporal sequence of events (Bruner, 1991; Richardson, 2000) with causal connections between those events (Richardson, 2000).

Although narrative *production* and narrative *comprehension* are interrelated, the two should be considered separately, as these two functions can comprise different processes. Narrative production may include narrative comprehension at its heart, as a story must first be understood to be told/retold. But narrative production also requires other skills, such as framing the story in a coherent manner that is understandable to the listener and using appropriate morphological and syntactic structures, which distinguish it as a separate process from comprehension. Narrative production studies have occasionally tested spontaneous narrative production in which participants tell a story such as a personal experience (e.g. Losh & Capps, 2003), which involves describing experienced events within a self-generated narrative structure. Spontaneous narrative is also often elicited by asking participants to recount the plot of a wordless picture book (AbdulSabur et al., 2014; Diehl, Bennetto, & Young, 2006; Losh & Capps, 2003; Tager-Flusberg, 1995; see reviews in Berman, 2009; Liles, 1993). Still other studies have examined retell, in which participants recount the plot of a spoken narrative (Diehl et al., 2006). Note that in retell, and also in spontaneous production of wordless picture books, the original narratives

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(whether orally or visually presented) have a narrative structure that is then internalized and re-produced, whereas in truly spontaneous production (e.g. describing a personal experience) this narrative structure is created on-line by the storyteller. In both types of production studies, narratives are commonly analyzed in terms of the presence of linguistic features such as the use of references, temporality, and syntactic connectivity; these production abilities are used to examine cognitive, social, and linguistic development (Berman, 2009; Liles, 1993).

In contrast, "narrative comprehension" refers to the access of semantic information – how various themes, characters, and plotlines fit together – mediated by narrative structures (Cohn, 2013a, 2013b). Narrative comprehension has been assessed by, for example, asking participants to answer comprehension questions following presentation of a written or spoken narrative (Horowitz-Kraus, Buck, & Dorrmann, 2016; Nuske & Bavin, 2011; Schmithorst, Holland, & Plante, 2006; Yarkoni, Speer, & Zacks, 2008); to judge the coherence or comprehensibility of a written story (Ferstl & von Cramon, 2001; Martín-Loeches, Casado, Hernández-Tamames, & Álvarez-Linera, 2008); to verbally recall or retell a story (Martín-Loeches et al., 2008); or to arrange sentences to create a coherent story (Jolliffe & Baron-Cohen, 2000; see Mar, 2004, for a review).

1.1. Narrative production and comprehension in individuals with autism

Autism spectrum disorder (ASD) is a developmental disorder defined by deficits in social communication and interaction as well as restricted and repetitive behaviors or interests (APA, 2013). In practice, ASD often presents with a wide constellation of deficits in motor, sensory, cognitive, and social domains. Deficits in language processing, although no longer a diagnostic criterion (APA, 2013), often co-occur in ASD, and can have great functional consequences for many individuals. Language deficits are particularly prominent in higher-level processes such as semantics, syntax, and narrative production and comprehension (Groen, Zwiers, van der Gaag, & Buitelaar, 2008; Tager-Flusberg, Paul, & Lord, 2005).

Narrative production abilities in individuals with ASD have received considerable attention; many studies report deficits in personal and/or fictional storytelling in children and adults with ASD (Diehl et al., 2006; Losh & Capps, 2003; Tager-Flusberg & Sullivan, 1995). As a recent meta-analysis summarizes, children with ASD show poorer performance on variables related to both microstructure and macrostructure of narrative production, as well as lower use of internal state language, compared to TD peers (Baixauli, Colomer, Roselló, & Miranda, 2016).

Studies of narrative comprehension in individuals with ASD, although less numerous than production studies, have also suggested deficits in children and adults with ASD, including: difficulty arranging written sentences into coherent narratives (Jolliffe & Baron-Cohen, 2000); impairments in making inferences about stories (Jolliffe & Baron-Cohen, 2000; Kaland, Smith, & Mortensen, 2007; Nuske & Bavin, 2011); and atypical brain activation and connectivity when reading passages requiring inferences (Mason, Williams, Kana, Minshew, & Just, 2008). These difficulties with making inferences during comprehension, extracting the main theme of a narrative, and connecting meaningful elements of the discourse have been attributed to an inability to connect pieces of information to thematically link together linguistic elements (Jolliffe & Baron-Cohen, 2000; Vermeulen, 2015).

Since successful narrative comprehension underlies successful narrative production, impairments in narrative production in individuals with ASD could arise, in part, from impaired comprehension. However, in comparison to the number of narrative production studies, investigations of narrative comprehension abilities in individuals with ASD are relatively sparse. Our understanding of the narrative comprehension abilities of individuals with ASD is incomplete, making it difficult to fully interpret production abilities. In the current study, we seek to address this relative paucity in the literature and gain a more comprehensive picture of narrative abilities in individuals with ASD.

1.2. Neural correlates of narrative production and comprehension

Previous neuroimaging studies in typically developing (TD) individuals have demonstrated that narrative production and comprehension recruit largely overlapping brain regions, including parts of the language network (e.g. left inferior frontal gyrus and temporal lobe); areas involved in the construction and maintenance of a mental representation of the story (e.g. dorsomedial prefrontal cortex, precuneus, inferior parietal lobes); and areas involved in theory of mind (ToM; the ability to understand the mental states of others; e.g. medial prefrontal cortex, temporo-parietal junction) (AbdulSabur et al., 2014; Ferstl, Neumann, Bogler, & Von Cramon, 2008; Mar, 2004). However, production and comprehension also elicit dissociable patterns of brain activation, such as a greater reliance on motor regions in narrative production (AbdulSabur et al., 2014) and a more bilateral involvement of perisylvian language areas in narrative comprehension (AbdulSabur et al., 2014; Mar, 2004). Other studies have also proposed a more bilateral or right-hemisphere dominant pattern of activity for narrative comprehension (e.g., Karunanayaka et al., 2007; Schmithorst et al., 2006), although this conjecture has not always been empirically supported (e.g., Ferstl & von Cramon, 2001; Yarkoni et al., 2008).

Several of the neural regions underlying narrative comprehension are abnormally activated or connected in ASD during language processing, which may contribute to some of the observed differences in narrative comprehension in this population. For example, consistent with evidence of impaired ToM in autism, Mason et al. (2008) observed atypical activation of the ToM network during narrative comprehension in individuals with ASD. Individuals with ASD also showed reduced connectivity between the ToM network and left-hemisphere language areas during narrative comprehension (Mason et al., 2008). This research therefore suggests a neural basis for the observed narrative comprehension impairments in individuals with ASD.

Of particular relevance to the current study, electrophysiological studies have also documented impairments in several aspects of language comprehension in individuals with ASD (Braeutigam, Swithenby, & Bailey, 2008; Dunn & Bates, 2005; Dunn, Gaughan Jr., Kreuzer, & Kurtzberg, 1999; McCleery et al., 2010; Pijnacker, Geurts, van Lambalgen, Buitelaar, & Hagoort, 2010; Strandburg et al., 1993). The *N400* event-related potential (ERP) component, a negative-going deflection peaking approximately 400 ms (ms) after stimulus presentation, has been established as an index of semantic processing (Kutas & Federmeier, 2011). In TD individuals, N400 amplitude is reduced for semantically congruent stimuli (e.g., contextually congruent sentence-final words) relative to semantically incongruent stimuli (e.g., contextually incongruent sentence-final words; Kutas & Federmeier, 2011; Kutas & Hillyard, 1980; Lau, Phillips, & Poeppel, 2008). The amplitude difference between congruent and incongruent conditions is referred to here as the *N400 effect*. (For current purposes, the N400 is taken to reflect semantic processing and integration [Kutas & Hillyard, 1980; Lau et al., 2008] although other functional interpretations exist [e.g., Brouwer, Fitz, & Hoeks, 2012; see Kutas & Federmeier, 2011 for a broader discussion.]) The N400 has been localized to areas of the frontal and temporal cortices (Kutas & Federmeier, 2011), which aligns with neuroimaging studies of narrative comprehension. Following the N400, a later positive component (*LPC*, alternatively called the *P600*) is also sometimes observed (Pijnacker et al., 2010; Sassenhagen, Schlesewsky, & Bornkessel-Schlesewsky, 2014; van de Meerendonk, Kolk, Vissers, & Chwilla, 2010). This component is characterized by a more positive-going waveform for incongruent conditions compared to congruent conditions and generally occurs between approximately 500 and 900 ms. The LPC has been linked to later linguistic reanalysis (Sassenhagen et al., 2014; van de Meerendonk et al., 2010).

Individuals with ASD often show reduced or absent N400 effects for language compared to TD individuals (Braeutigam et al., 2008; Dunn & Bates, 2005; Dunn et al., 1999; McCleery et al., 2010; Pijnacker et al., 2010; Strandburg et al., 1993), suggesting difficulty with integrating