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Atypical perceptual and neural processing of emotional prosodic changes in children with autism spectrum disorders

R. Lindström[a,*], T. Lepistö-Paisley[a,c], T. Makkonen[a], O. Reinvall[b,c], T. Nieminen-von Wendt[d], R. Alén[e], T. Kujala[a]

[a] *Cognitive Brain Research Unit, Department of Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland*
[b] *Department of Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland*
[c] *Department of Pediatric Neurology, Helsinki University Hospital, Helsinki, Finland*
[d] *Neuropsychiatric Rehabilitation and Medical Centre NeuroMental, Helsinki, Finland*
[e] *Department of Child Neurology, Central Finland Central Hospital, Jyväskylä, Finland*

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HIGHLIGHTS

- Anomalous neural prosody discrimination in children with autism spectrum disorder (ASD).
- Impaired orienting to prosodic changes in children with ASD.
- Sluggish perceptual prosody discrimination in children with ASD.

ABSTRACT

Objective: The present study explored the processing of emotional speech prosody in school-aged children with autism spectrum disorders (ASD) but without marked language impairments (children with ASD [no LI]).
Methods: The mismatch negativity (MMN)/the late discriminative negativity (LDN), reflecting pre-attentive auditory discrimination processes, and the P3a, indexing involuntary orienting to attention-catching changes, were recorded to natural word stimuli uttered with different emotional connotations (neutral, sad, scornful and commanding). Perceptual prosody discrimination was addressed with a behavioral sound-discrimination test.
Results: Overall, children with ASD (no LI) were slower in behaviorally discriminating prosodic features of speech stimuli than typically developed control children. Further, smaller standard-stimulus event related potentials (ERPs) and MMN/LDNs were found in children with ASD (no LI) than in controls. In addition, the amplitude of the P3a was diminished and differentially distributed on the scalp in children with ASD (no LI) than in control children.
Conclusions: Processing of words and changes in emotional speech prosody is impaired at various levels of information processing in school-aged children with ASD (no LI).
Significance: The results suggest that low-level speech sound discrimination and orienting deficits might contribute to emotional speech prosody processing impairments observed in ASD.

1. Introduction

Deficient social communication skills, narrow interests, and repetitive behavior are the main diagnostic features of autism spectrum disorders (ASD) (APA, 2013). Some individuals with ASD show significant delays and abnormalities in their language development (later referred to as children with ASD (LI) in this article), whereas some individuals with ASD show rather typical formal language development (later referred to as children with ASD (no LI)) (WHO, 1993; Rapin and Dunn, 2003; Gillberg and Coleman, 2000). However, individuals with ASD (no LI) may have deficits in semantic-pragmatic language skills (Gillberg and Coleman, 2000).

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[*] Corresponding author at: Cognitive Brain Research Unit, P.O. Box 9, FIN-00014, University of Helsinki, Finland.

E-mail address: riikka.h.lindstrom@helsinki.fi (R. Lindström).

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Semantic and pragmatic information, as well as information on the speaker's intentions and emotions, are conveyed by speech prosody (for reviews, see Wagner and Watson, 2010; Witteman et al., 2012). The f0, intensity, and duration changes in speech mainly carry the prosodic information (Wagner and Watson, 2010; Witteman et al., 2012). It has been shown that emotional speech prosody activates the auditory cortices irrespective of listeners' attention, suggesting that the early phases of emotional prosody detection are pre-conscious (Ethofer et al., 2006; Grandjean et al., 2005; for reviews, see Kotz and Paulmann, 2010; Brück et al., 2011). At the later stages, the acoustic cues are integrated, and finally, the emotional information carried by the vocalizations is evaluated (Schirmer and Kotz, 2006; Kotz and Paulmann, 2010; Brück et al., 2011).

Even though atypical prosody production is often documented in ASD (Shriberg et al., 2001; for a review, McCann and Peppé, 2003), behavioral studies of speech prosody comprehension in ASD show conflicting results. Some studies suggest that individuals with ASD have difficulties understanding emotional prosody (Golan et al., 2007; Peppé et al., 2007; Rutherford et al., 2002; Lindner and Rosén, 2006; Chevallier et al., 2011; McCann and Peppé, 2003). Children with ASD were less accurate in matching vocal emotional expressions with facial emotional expressions than their typically developed peers (Linder and Rosén, 2006). Also, they had difficulties judging, whether the speaker was liking or disliking food based on the speech prosody (Peppé et al., 2007). Consistently, adults with ASD have been found to score lower than the control group when matching spoken phrases presented with different emotional prosody with written labels of emotions (Rutherford et al., 2002; Golan et al. 2007).

In contrast, some studies suggest rather typical emotional prosody comprehension in ASD. Children with ASD were shown to have no difficulties in naming vocally expressed emotions from spoken words (Boucher et al., 2000). Also, children and adolescents with ASD had no deficits in recognizing emotions from spoken sentences or pseudo language utterances (Heikkinen et al., 2010; Brennand et al. 2011; Le Sourn-Bissaoui et al., 2013; Grossman et al., 2010; Chevallier et al., 2011). However, adolescents with ASD had difficulties comprehending the emotional vocal cues from sentences when being under a high cognitive load (Chevallier et al., 2011).

The variation in the instructions and cognitive task demands might contribute to the above mentioned conflicting behavioral results on emotional speech prosody comprehension in ASD. Therefore, the auditory event related potentials (ERPs), including components that are elicited task-independently, could serve as a suitable tool for investigating prosody processing in ASD (Taylor and Baldeweg, 2002). Repetitive speech sounds elicit the P1, N2, and N4 deflections that reflect the detection and encoding of speech in children (Čeponienė et al., 2008). It was suggested that the P1 reflects the detection of physical stimulus features of sounds, whereas the N2 and N4 reflect more complex sound analysis (Čeponiené et al., 2001, 2005, 2008, such as the "speechness" of the stimuli (Čeponienė et al., 2008). Previous studies have reported diminished N4 amplitudes both in children with ASD (LI) (Lepistö et al., 2005) and in children with ASD (no LI) (Lepistö et al., 2006) for repetitive vowels. Also, diminished ERPs to a repetitive word stimulus were found in children with ASD (LI) (Lindström et al., 2016).

The mismatch negativity (MMN), in turn, reflects pre-conscious auditory discrimination and it is elicited by any discriminable change in physical or even abstract properties of sounds in a sound sequence (Kujala and Näätänen, 2010). The MMN amplitude and latency reflect sound discrimination accuracy; MMNs with large amplitudes and short latencies are associated with more accurate and speeded behavioral sound discrimination (Kujala and Näätänen, 2010). In children, another change-related ERP deflection, the late discriminative negativity (LDN), can follow the MMN within 400–600 ms from the deviant stimulus onset (Korpilahti et al., 1995, 2001; Čeponiené et al., 1998; for reviews, see Cheour et al., 2001; Wetzel et al., 2014). However, the brain processes underlying the LDN elicitation are still poorly understood (Wetzel et al., 2014). Distracting sound changes elicit a positive deflection called the P3a that reflects involuntary attention switching processes (Escera et al., 2000; Escera and Corral, 2007). The P3a amplitude indexes the magnitude of the sound change: more distracting sounds elicit P3a with a larger amplitude than minor sound changes (Escera et al., 2000).

ERP studies on natural speech prosody processing in ASD are scarce. Diminished MMN for scornful prosodic sound changes and prolonged MMN latency for commanding deviants, suggesting aberrant neural discrimination of emotional prosody, were found in adults with ASD (no LI) (Kujala et al., 2005). Lindström et al. (2016), in turn, investigated children with ASD (LI) with the same word stimuli used in Kujala et al. (2005) study by presenting the children a repetitive neutral word stimulus that was occasionally replaced by scornfully, commandingly, or sadly uttered word. They showed a diminished MMN/LDN for the scornful prosodic change, peaking at about 500 ms from the deviant stimulus onset, in these children. Thus, the results of Lindström et al. (2016) and Kujala et al. (2005) suggest hyposensitive neural discrimination of emotional prosodic speech changes in ASD. However, Korpilahti et al. (2007) reported enhanced MMNs to an angrily uttered deviant word stimulus presented occasionally among tenderly-uttered words in school-aged children with ASD (no LI), suggesting hyperactive neural responsiveness for this prosodic change.

In Lindström et al. (2016) study, the P3a elicited by the scornful deviant was diminished in amplitude in children with ASD (LI), suggesting impaired orienting to emotional speech sound changes in the ASD group. However, to our knowledge, it has so far not been determined whether involuntary orienting to emotional prosodic changes in natural speech, as reflected by the P3a, is abnormal in children with ASD (no LI).

The aim of the current study was to explore how school-age children with ASD (no LI) detect and encode physical stimulus features of naturally-spoken words and how they behaviorally and neurally discriminate and involuntarily orient to prosodic changes in these words uttered with different emotional connotations. We used the same ERP paradigm that was previously applied in investigating children with ASD (LI) (Lindström et al., 2016). Based on the studies by Chevallier et al. (2011) and Peppé et al. (2007), the children with ASD were hypothesized to have lower hit rates and slower reaction times for prosodic changes in the sound discrimination test than the control participants. Based on our previous results (Lindström et al., 2016), it was hypothesized that the participants with ASD would show ERP responses diminished in amplitude to a repetitive word stimulus. Further, it was hypothesized that they would show diminished MMN/LDNs to the sad and scornful prosodic deviants including minor acoustic changes in the stimuli. However, based on Korpilahti et al. (2007), we expected an enhanced MMN/LDN to the commanding deviant. Finally, based on Lindström et al. (2016), the prosodic changes were expected to elicit diminished P3a in children with ASD (no LI).

2. Methods

2.1. Participants

16 children with ASD (no LI) and 16 control children were recruited for the experiment. However, as a result of noisy EEG signal, the data of one participant with ASD were rejected. Due to