Physiology & Behavior 196 (2018) 47–58

Contents lists available at ScienceDirect

Physiology & Behavior

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

Neural evidence for reduced automaticity in processing emotional prosody among men with high levels of autistic traits

Ming Lui[a,*], Wing-Chee So[b], Yiu-Kei Tsang[a]

[a] Department of Education Studies, Hong Kong Baptist University, Hong Kong, China
[b] Department of Educational Psychology, Chinese University of Hong Kong, Hong Kong, China

ARTICLE INFO

Keywords:
Autistic traits
Emotions
Speech comprehension
Communication
Language processing

ABSTRACT

This study aimed to examine individual differences in the integration of emotional prosody when processing semantic meaning in speech among men with high and low levels of autistic traits, as measured by the Autism Spectrum Quotient (AQ). The behavioral and neural responses of high- and low-AQ men during semantic valence judgment were compared. The stimuli were positive or negative words spoken with either happy or sad prosody; in other words, the prosody was either congruous or incongruous to the valence of meaning. Participants were required to judge the (positive vs. negative) valence of word meaning as accurately and as quickly as possible while ignoring emotional prosody. Behavioral results showed that high-AQ men responded significantly more slowly than low-AQ men in all stimulus conditions, indicating lower automaticity in processing emotional speech. Neural data revealed that low-AQ men (but not high-AQ men) had significantly increased N200 and N400 amplitudes for incongruous (compared to congruous) stimuli spoken with happy prosody. Our findings supported our hypotheses that high levels of autistic traits are associated with reduced behavioral automaticity and less differential neural resources allocated to processing emotional speech stimuli with different cognitive demands.

1. Introduction

In human interactions, the success with which a person communicates with others depends on the ability to recognize other people's emotions, which are expressed through verbal and non-verbal communication. Past studies have shown individual differences in the ability to recognize emotions. For example, people with autism spectrum disorders (ASD) are less able to accurately recognize subtly expressed complex facial expressions, such as shame and embarrassment (e.g., [8,23,31]). Beside facial expressions, speech is a major channel of human communication. In some real-life situations, such as chatting on the phone, speech is the only channel through which the speaker's message can be interpreted, as there is no access to visual cues from information gained through other features of communication, such as facial expression, body posture, gesture, and rate and grace of movement. There are two major components of speech through which speakers' emotions are conveyed: the semantic meaning of words and the emotional prosody of their voice, which are verbal and non-verbal signals, respectively. Past studies have found that participants with ASD have deficits in processing the semantic meanings of emotional words (for a review, see [49]). These deficits have been further demonstrated in studies using either implicit measures, such as memory tasks [14,15], or explicit measures, such as emotion-identification tasks [21,48].

The other component of speech, emotional prosody, refers to variations in acoustic properties, such as pitch, intensity, and duration, which reflect the emotional state of the speaker [40]. Past studies on the processing of emotional prosody have required participants to listen to words or sentences varying in prosody, while controlling for their semantic meaning (e.g., [5,12,18]). The findings of these studies are, however, highly inconclusive. Some others have revealed deficits in the processing of emotional prosody among individuals with ASD across age groups (for children, see [3]; for adults, see Rutherford, Baron-Cohen, &Wheelwright, 2002; [17]). Other studies on children and adolescents have found no differences between participants with ASD and control group participants in terms of accuracy in recognizing emotional prosody ([5,18]; Lyons, Schoen, Simmons, & Paul, 2014).

While past studies have compared individuals with ASD to control group in their abilities to recognize emotions, one important research gap in the literature is the lack of studies examining how autistic traits influence the automaticity of emotional prosody processing, particularly among the non-clinical general population. In cognitive psychology, automaticity in mental processes refers to the way in which

* Corresponding author.
E-mail address: m-lui@u.northwestern.edu (M. Lui).

https://doi.org/10.1016/j.physbeh.2018.08.014
Received 12 March 2018; Received in revised form 21 August 2018; Accepted 24 August 2018
Available online 26 August 2018
0031-9384/

information is processed in a highly efficient manner, with little mental effort and awareness [32]. As the emotions conveyed in daily interactions are often brief and transient, one needs to process and respond to emotional signals rapidly, which requires high level of automaticity in processing. Most past studies instructed participants to identify emotional prosody and measured the accuracy of their responses (e.g., [5,18,30]). Our study, however, has an implicit measure of automaticity, requiring participants to ignore emotional prosody while attending to the valence of auditory words' semantic meaning. A higher automaticity of processing emotional prosody would be reflected by a poorer ability to ignore emotional prosody while participants make semantic judgment.

Furthermore, most previous autism studies have examined *either* emotional prosody or the semantic meaning of speech (e.g., [5,18]). Studies examining the integration of emotional signals from multiple channels of communication are lacking. In daily conversation, it is not uncommon to find conflicts of valence between emotional prosody and semantic meaning, such as in sarcasm and humor. Accurate interpretation of a speaker's messages usually depends not on a single channel but the integration of signals from multiple channels in communication. A previous study investigated the speed and accuracy of children with and without ASD in judging the emotional state of speakers when the valence of semantic meaning and prosodies of words was congruous and incongruous [44]. Note that when the children participants perform the task, they could rely on either prosodic or semantic information (or both), as the task did not specify the channel of information they should rely on when making the judgment. The results showed that both groups of children were slower in incongruous conditions than in congruous conditions. However, since the children were required to make prosodic and semantic judgment of words in two separate baseline blocks before the major task of judging the speaker's emotions, these baseline tasks may have primed the children to process both prosodic and semantic information while judging, thereby reducing the differences between children with and without ASD.

In this study, we aimed to examine automaticity in integrating emotional prosody in speech processing by requiring participants to judge the semantic meaning of words while ignoring the emotional prosody. Participants listened to positive and negative words spoken with either happy or sad tones. In other words, the valence of meaning and prosody was either congruous or incongruous. As our task did not require the processing of emotional prosody, any behavioral differences between congruous and incongruous stimulus conditions indicated the involuntary or automatic integration of emotional prosody into the semantic processing of speech. We examined our research questions with both neural and behavioral measures. Participants' autistic traits were measured by the Autism Spectrum Quotient (AQ; [2]), a self-administered instrument for measuring the degree of autistic traits of an adult of normal intelligence. According to the Research Domain Criteria (RDoC) proposed by the U.S. National Institute of Mental Health (NIMH), mental disorders should be regarded as the extreme ends on a continuum spanning the entire population of healthy to malfunctioning individuals. In other words, the non-clinical population exhibits a wide range of characteristics associated with ASD. We therefore utilized AQ to assess the degree of autistic traits among non-clinical samples and examined whether autistic traits have an effect on automaticity in integrating emotional prosody during speech processing.

Our first hypothesis was that high-AQ participants would present less automaticity in processing emotional speech, which manifests as slower reaction times. Second, we hypothesized that high-AQ participants would present less integration between emotional prosody and word meaning when listening to speech stimuli. This would be reflected by diminished differences between congruous and incongruous stimulus conditions in terms of reaction time and accuracy among high-AQ participants. Third, we hypothesized that only low-AQ participants would show a significant difference between congruous and incongruous stimuli in event-related potential (ERP) data. A negative-going ERP component, N400, has been found to be sensitive to semantic incongruity in language processing (e.g., [20,27]). A lack of N400 amplitude difference between congruous and incongruous conditions implies that no additional mental resources are being allocated to fulfill the higher cognitive demands caused by the conflicting information in incongruous conditions.

2. Material and methods

2.1. Participants

Cantonese-speaking participants were recruited through an online advertisement linking to an online version of the AQ [2]. One thousand four hundred and sixty males and females completed the online AQ. The mean AQ score was 21.58 (SD = 5.96). Forty-one male respondents who fulfilled the selection criteria participated in the experiment. The selection criteria included AQ scores (high AQ range ≥24; low AQ range ≤17), age (18–30 years), sensory abilities (no diagnosed hearing or visual impairment), handedness (right-handed), and self-reported medical history (no diagnosed neurological or psychological disorders, including ASD). Participants' data were excluded due to excessive eye or movement artifacts during electroencephalogram (EEG) recordings ($N = 5$), anxiety and/or depression based on the 7-item Generalized Anxiety Disorder scale (GAD-7) and the Center for Epidemiologic Studies Depression Scale Revised (CESD-R-10) ($N = 4$), alcohol intake within 24 h ($N = 1$), and failure to follow instructions ($N = 1$). The final data set thus contains 30 male tertiary institution students or graduates and aged between 19 and 27 ($M = 21.63$; $SD = 2.25$) (Table 1). Fifteen participants whose AQ scores were among the top 35% of the 1460 respondents were considered high-AQ while fifteen participants whose AQ scores were among the bottom 35% were considered low-AQ. The Mann-Whitney U test revealed that high-AQ participants (AQ *Mean* = 29.07; *SD* = 2.96) had significantly higher AQ scores than low-AQ participants (AQ *Mean* = 13.07; *SD* = 2.37; Mann-Whitney U = 0.00, $p < .001$). All participants completed the Empathy Quotient questionnaire (EQ; [1]). High-AQ participants (EQ *Mean* = 26.93; *SD* = 7.53) had significantly lower EQ than low-AQ participants (EQ *Mean* = 43.73; *SD* = 6.67; Mann-Whitney U = 9.50, $p < .001$). The participants also completed a 30-minute speeded version of Raven's Advanced Progressive Matrices Test [37] to assess their non-verbal IQ. High-AQ participants (Raven's *Mean* = 25.54; *SD* = 4.63) had significantly higher Raven's scores than low-AQ participants (Raven's *Mean* = 21.29; *SD* = 5.40; Mann-Whitney $U = 48.50$, $p < .05$).

A power analysis was performed using the G*Power 3.1 software. Referring to a previous ERP study assessing the processing of congruency between emotional prosody and semantic meaning among non-clinical samples (Paulman & Kotz [36]), the main and interaction effects had medium to large effect sizes ($\Omega^2 = 0.08–0.11$). Our

Table 1
Descriptive statistics of participants' Autism Spectrum Quotient (AQ), Empathy Quotient (EQ), Raven's Advanced Progressive Matrices score (Raven's), and age. Results of statistical comparisons between low AQ and high AQ group using Mann-Whitney U test were indicated under the columns U and p.

	Group	N	Mean	SD	Min.	Max.	U	p
AQ	Low AQ	15	13.07	2.37	9	17	0.00	0.000
	High AQ	15	29.07	2.96	24	36		
EQ	Low AQ	15	43.73	6.67	30	58	9.50	0.000
	High AQ	15	26.93	7.53	13	39		
Raven's	Low AQ	15	21.29	5.40	10	29	48.50	0.038
	High AQ	15	25.54	4.63	14	33		
Age	Low AQ	15	21.33	2.26	19	27	97.5	0.539
	High AQ	15	21.93	2.28	19	26		

Note. p denotes exact significance.