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BRIEF REPORT

Brief Report: Emotional Picture and Language Processing in Adults with Autism Spectrum Disorder

Tammy Y. Q. Wong[1] · Melvin J. Yap[1] · Takashi Obana[2,3] · Christopher L. Asplund[1,2,3] · Elizabeth J. Teh[4]

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Abstract

There is currently limited research and a lack of consensus on emotional processing impairments among adults with autism spectrum disorder (ASD). The present pilot study sought to characterize the extent to which adults with ASD are impaired in processing emotions in both words and pictures. Ten adults with ASD rated word and picture stimuli on emotional valence and arousal. Their ratings were compared to normative data for both stimuli sets using item-level correlations. Adults with ASD rank-ordered stimuli similarly to typically developing individuals, demonstrating relatively typical understanding of emotional words and pictures. However, they used a narrower range of the scales which suggests more subtle impairments affecting emotion-processing. Future directions arising from the findings of this pilot study are discussed.

Keywords Autism spectrum disorders · Adults with ASD · Emotional processing · Valence ratings · Arousal ratings · Pictures · Word stimuli

Introduction

Autism spectrum disorder (ASD) comprises a range of conditions characterized by deficits in social communication and restricted or repetitive patterns of behaviour, activities or interests (American Psychiatric Association 2013). To date, literature in the field of autism is overrepresented by children with ASD while less emphasis is placed on their adult counterparts (Howlin and Moss 2012). Yet, the study of the latter is crucial as they face more pronounced difficulties with the increasingly complex environments in which they operate (McVey et al. 2016). In particular, emotional processing abilities amongst individuals with ASD is a critical area of study as such abilities are implicated in important aspects of functioning and quality of life (Schonert-Reichl 1993).

A meta-analysis of facial emotion recognition studies revealed impairments in individuals with ASD compared to typically developing (TD) individuals, with a large mean effect size of Cohen's $d = 0.80$ (Uljarevic and Hamilton 2013). However, there is presently a lack of nuanced understanding of emotional processing beyond facial processing (Lartseva et al. 2014). Findings are mixed as to whether adults with ASD display an impairment in emotional processing of non-facial stimuli, including linguistic (word-based) and non-linguistic (picture-based) stimuli. In contrast, in the TD population, emotional processing of words and pictures is well-studied (Lartseva et al. 2015). In this brief report, we present a pilot study investigating emotional response and perception abilities in adults with ASD, compared to TD normative abilities, using two emotional rating tasks involving words and pictures.

Mixed Findings on Emotional Processing in Adults with ASD

Researchers have employed various paradigms to study emotional processing in adults with ASD, including emotional recognition, memory, and rating paradigms. Emotional tasks have also differed in the extent of language processing

✉ Elizabeth J. Teh
entejt@nus.edu.sg

1 Department of Psychology, National University of Singapore, Singapore, Singapore

2 Division of Social Sciences, Yale-NUS College, National University of Singapore, Singapore, Singapore

3 N.1 Institute for Health, National University of Singapore, Singapore, Singapore

4 Department of Otolaryngology, Division of Graduate Medical Studies, Yong Loo Lin School of Medicine, National University of Singapore, MD3, Level 2, 16 Medical Drive, Singapore 117600, Singapore

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required, as existing experimental stimuli include text (words or sentences), pictures, or combinations of text and pictures. While these paradigms may differ in task-specific demands, they converge in generally tapping emotional processing skills. However, findings have been mixed to date and this discrepancy may be partially attributable to the different paradigms and stimuli used across studies. Table 1 summarizes relevant studies that have used linguistic and non-linguistic stimuli, and their general findings.

In terms of linguistic stimuli, when participants were presented with emotional and non-emotional words and sentences, Beversdorf et al. (1998) found that TD adults showed enhanced recall of emotional compared to unemotional material, but the same pattern was not shown by adults with ASD. Lartseva et al. (2014) reported emotional facilitation effects for lexical decisions (i.e., does a letter string form a word or nonword?) in ASD and TD groups, but observed atypical event-related potentials (ERP) response patterns to negative stimuli in the ASD group. On the other hand, South et al. (2008) found that individuals with ASD performed similarly to the TD controls, in that both groups responded faster to negative than emotionally-neutral and positive words, and to high-arousal than neutral-arousal and low-arousal words (e.g., 'crash' vs 'paper'). The results suggest that aspects of emotional processing for linguistic stimuli were intact in the ASD group, perhaps influenced by specific valence and/or arousal conditions. To date, the evidence is too mixed for a conclusion on whether the processing of emotional linguistic stimuli is impaired in ASD. Further, a systematic review by Lartseva et al. (2015) found that while individuals with ASD may be able to correctly identify the emotionality of words, their processing of emotional language seems to deteriorate when tested in paradigms involving memory, automatic information-processing and in discourse and reasoning.

For non-linguistic stimuli,Wilbarger et al. (2009) found that adults with ASD produced atypical physiological responses to emotional images but similar responses in terms of valence and arousal ratings,[1] compared to TD individuals. Trimmer et al. (2017) found the opposite; adults with ASD showed similar physiological responses to emotionally distressing video clips as TD controls, but produced dampened (i.e., less negative) self-report ratings. Kruger et al. (2018) required participants to rate the valence of emotions depicted by people in videos using point-light displays and reported that participants with ASD tended to rate positive videos more negatively than did the TD controls. Their ratings were also lower in intensity, suggesting an altered perception of emotions in ASD (Kruger et al. 2018). A more recent study by Tang et al. (2019) found that adults with high functioning autism performed similarly to TD controls when it came to recognizing emotions in naturalistic social scenes (see Table 1). In summary, studies involving non-linguistic stimuli have yielded equally mixed findings as those involving linguistic stimuli about the emotional processing abilities of adults with ASD. Our study aims to address this gap.

Minshew and Goldstein's (1998) theory of complex information-processing explores how adults with ASD might perform differently when processing emotional pictures and texts. This theory posits that individuals with ASD perform worse on cognitive-processing tasks when more cues need to be processed simultaneously. Specifically, impairment in emotional processing in adults in ASD may be limited to situations in which additional complex cues need to be processed simultaneously, such as: (a) presenting picture stimuli with multiple emotional cues or (b) having participants perform linguistic tasks that place demands on both language- and emotional processing. Alternatively, the weak central coherence account posits that while TD individuals prefer global processing to local processing, individuals with ASD tend to process information in a way that is detail-oriented, with focus on the individual components rather than the whole (Happé and Frith 2006). As such, they may struggle with perceiving emotionality in situations where the emotional meaning of a stimulus is apparent only when perceived as a whole and in its context. Finally, according to the theory of mind account, individuals with ASD face difficulty in attributing mental states, including emotions (Lombardo et al. 2007), yet this ability is required to derive emotional meaning from text or to deduce what someone else is feeling (Lartseva et al. 2015).

The various theoretical models above are unable to fully account for the mixed patterns of emotional skills and deficits reported in ASD to date. Current findings do not agree on whether individuals with ASD are necessarily impaired in emotional processing, and in response to what types of stimuli in particular. The use of different experimental paradigms with different task-specific requirements may have further muddied the picture. Moreover, the valence and arousal conditions of the stimuli may play a moderating role, warranting further examination of their influence on emotional processing in ASD.

The Present Study

With the variability in experimental tasks and emotional performance described above, there are existing gaps in the literature concerning whether and under what conditions adults with ASD display an impairment in emotional processing compared to normative behaviour. The present pilot study attempts to uncover some answers to this question.

[1] The valence of a stimulus refers to its pleasantness while arousal refers to the amount of stimulation it evokes (Bradley and Lang 1999; Dichter et al. 2010).

Table 1 Summary of Findings on Emotional Processing in Adults with ASD

Study	Participants		Experimental stimuli		Findings (Impairment or no impairment)
	Sample	Age range	Linguistic or non-linguistic	Valence	
Beversdorf et al. (1998)	HFA (n = 10) TD (n = 13)	18 and above	Linguisitic; audioclips of emotional and neutral sentences	N. R	Impairment; TD group recalled more of the emotional than neutral sentences while ASD group did not show this difference
Bodner et al. (2015)	ASD (n = 86) TD (n = 65)	20.6 (9.1) 22.6 (8.4)	Linguistic; experimenter's narration of short stories from Pittsburg Inference Test	N. R	Impairment; ASD group had more difficulty making inferences, especially those related to emotional understanding
Gaigg and Bowler (2009)	ASD (n = 22) TD (n = 22)	33.5 (12.3) 35.2 (9.6)	Linguistic; emotional and neutral words	Negative and neutral	Impairment; TD group less likely to experience false memories of emotional than neutral words, but ASD group did not show this emotional modulation of false memories
Lartseva et al. (2014)	HFA (n = 21) TD (n = 20)	26.9 (5.6) 24.3 (4.3)	Linguistic; emotional and neutral Dutch words	Positive, negative and neutral	Mixed; ASD group had slower reaction time (RT) than TD group on a lexical decision task, but no significant difference in response accuracy. Both groups showed emotion facilitation effects for RT and accuracy, although EEG data found that the ASD group showed no late positive component in response to emotional words while the TD group did
South et al. (2008)	ASD (n = 37) TD (n = 38)	19.7 (5.3) 19.2 (6.0)	Linguistic; emotional and neutral words	Positive, negative and neutral	No impairment; both TD and ASD groups reacted faster when asked to recall negative than neutral and positive words, and high-arousal than neutral and low-arousal words
			Non-linguistic; threat-relevant (e.g., snakes) versus threat-irrelevant stimuli (e.g., flowers) in 3 × 3 photographic array visual search	Negative and neutral	No impairment; both TD and ASD groups reacted faster to threat-relevant stimuli than threat-irrelevant stimuli
Boraston (2008)	ASD (n = 11) TD (n = 11)	36.7 (4.32) 33.8 (13.2)	Non-linguistic; video clips of animated shapes	Positive and negative (*'happy', 'angry', 'sad', 'scared'*)	Impairment; ASD group performed poorer than TD group in recognizing 'sadness' in animations
Deruelle et al. (2008)	ASD (n = 15) TD (n = 15)	29 (11.5) 25.4 (3.4)	Non-linguistic; pictures from IAPS	Positive, negative and neutral	Impairment; TD group recalled negative pictures better than neutral and positive pictures, but ASD group recalled neutral and emotional pictures similarly
Krüger et al. (2018)	ASD (n = 16) TD (n = 16)	34.7 (10.9) 35 (10.7)	Non-linguistic; video clips of actors performing particular emotions depicted using point-light displays	Positive, negative and neutral	Impairment; ASD group rated positive emotional interactions as more negative than TD group; no difference for negative interactions

Table 1 (continued)

Study	Participants		Experimental stimuli		Findings (Impairment or no impairment)
	Sample	Age range	Linguistic or non-linguistic	Valence	
Philip et al. (2010)	ASD (n = 23) TD (n = 23)	32.5 (10.9) 32.4 (11.1)	Non-linguistic; video clips of whole-body movement	Positive and negative (*'happiness', 'sadness', 'anger', disgust' and 'fear'*)	Impairment; ASD group displayed deficits in recognising emotions (especially 'happiness' and 'fear') from body movements
Trimmer et al. (2017)	ASD (n = 25) TD (n = 25)	29 (13.8) 28 (9.2)	Non-linguistic; emotionally distressing video clips	Negative and neutral	Mixed; impairment in self-reported valence ratings but not physiological responses
Tang et al. (2019)	ASD (n = 23) TD (n = 25)	25.3 (8.9) 27.3 (9.0)	Non-linguistic; video clips of social scenes	N. R	No impairment; ASD group displayed comparable emotion recognition to TD group (but showed divergent eye-gaze patterns toward non-social information)
Wilbarger et al. (2009)	ASD (n = 14) TD (n = 14)	21.9 (7.5) 21.1(5.7)	Non-linguistic; pictures from IAPS	Positive, negative and neutral	Mixed; impairment in startle responses but not self-report valence ratings

HFA high functioning autism, *IAPS* the international affective picture system, *NR* information was not reported in the study

Specifically, we aim to investigate whether adults with ASD process emotional valence and arousal similarly to TD adults. We selected two emotional experiments—a word-rating and picture-rating task—that are well established in the TD literature. These tasks were chosen for being relatively low in the cognitive demands required beyond emotional processing. We conduct item-level correlations of the ASD and TD ratings for each set of stimuli, as well as by valence conditions within each set, with higher correlations indicating a closer-to-normative performance by the adults with ASD. Our pilot study features two novel aspects: first, it uses item-level correlations to compare ASD and TD performance to examine effects of stimuli valence on processing, and second, it employs a word-rating task as a method of tapping into emotional processing in a sample of participants with ASD. Understanding the specific conditions in which individuals with ASD struggle can better inform emotion research practices and our findings will help inform future research in this field.

Method

Participants

Ten adults (mean age: 28.3 years, $SD = 4.92$) with clinical diagnoses of high-functioning autism (HFA) or Asperger's syndrome participated in this study. Eight participants were males and two were females. The Autism Diagnostic Observation Schedule 2nd edition (ADOS-2; Lord et al. 2012) was administered by an experienced clinician, who is qualified as research-reliable for ADOS-2, to verify participants' diagnoses. ADOS communication and social interaction total scores ranged from 7 to 19 ($Mean = 11.7$, $SD = 4.2$); five participants reached criteria for autism and four for autism spectrum.[2] Participants also underwent the Kaufman Brief Intelligence Test (KBIT; Kaufman and Kaufman 1990) as a measure of verbal IQ ($Mean = 94$; $SD = 11.6$) and nonverbal IQ ($Mean = 108.5$, $SD = 13.9$), and completed a demographic questionnaire. All participants' dominant language was English. Eight participants (80%) had completed tertiary education (diploma or bachelor's degree or higher), and a majority of them (70%) were under regular employment. (Sample characteristics are summarized in Table 2).

Materials

Two sets of stimuli were used, one for each rating task. The picture-based stimuli comprised 203 line-drawings (see

[2] One participant did not undergo ADOS-2 testing due to resource constraints, but provided documentation of diagnosis as verification.

Table 2 Summary characteristics of participants

	Number of participants ($N = 10$)	Proportion of participants (%)
Gender		
Male	8	80
Female	2	20
Highest educational level		
Primary education	1	10
Vocational education	1	10
Diploma	1	10
Bachelor's degree	6	60
Master's degree	1	10
Language background		
Dominant language: English	10	100
Dominant language: Others	0	0
Other language(s) Chinese (Mandarin)	9	90
Malay	2	20
Japanese	1	10
Tagalog	1	10
Employment		
Currently schooling	1	10
Regular employment	7	70
Supported employment	1	10
No employment	1	10
Housing		
Resides with family	10	100
Living alone/lives with housemates/other institutional care setting	0	0
Social		
Has one or two best friends	6	60
Has several best friends	2	20
Has no best friends	2	20
Cognitive skills	*M (SD)*	
Verbal IQ	94 (11.6)	
Non-verbal IQ	108.5 (13.9)	
Composite IQ	101.8 (10.8)	
ADOS-2 ($n = 9$)	11.7 (4.2)	

example in Fig. 1) from the Pictures with Social Context and Emotional Scenes database (PiSCES; Teh et al. 2018), and the word stimuli contained 203 words from Warriner et al. (2013) English lemmas. The PiSCES database comprises 203 pictures with reported norms for valence, arousal and social engagement ratings (Teh et al. 2018).To select the word stimuli for this study, the reported norms for both pictures and words were standardized using *z*-scores, then matched on valence and arousal. For each picture in the PiSCES database, a word from Warriner et al.'s (2013) database ($N = 13{,}915$) with comparable valence and arousal

Fig. 1 Example line-drawing from PiSCES database (Teh et al. 2018), depicting people within a contextual situation

z-scores was chosen to derive 203 matched words. A paired samples *t*-test confirmed that the two sets of stimuli did not differ in both valence [$t(202) = 0.198$, $p = 0.843$] and arousal ratings [$t(202) = 0.852$, $p = 0.395$]. (See Appendix Table 5 for list of word stimuli.)

Experimental Procedures

Picture-Rating Task

The experimental procedures replicated the method used to obtain TD norms for the PiSCES database (Teh et al. 2018). Participants were presented a series of pictures individually. To collect ratings on the emotional conditions represented by the pictures, participants were asked to adopt the perspective of the person(s) in the pictures. Participants rated each picture using 7-point Likert scales for three variables in this order—emotional valence (from 1 = strongly negative, to 7 = strongly positive), arousal (from 1 = extremely low, unaroused, to 7 = extremely high, strongly aroused), and social engagement (from 1 = completely no interaction or engagement with another person, to 7 = extremely high degree of interaction or engagement with other people).[3] Stimuli were presented in randomized order using E-Prime 2.0 (Psychology software tools, Pittsburgh, PA, USA) in the format illustrated in Fig. 2. All participants were presented with the complete set of 203 pictures, with an untimed (minimum of 1 min) break inserted after every 40 pictures to prevent participant fatigue. Participants took approximately 46 min on average to complete this task.

[3] For the purposes of the present study, only valence and arousal ratings are reported.

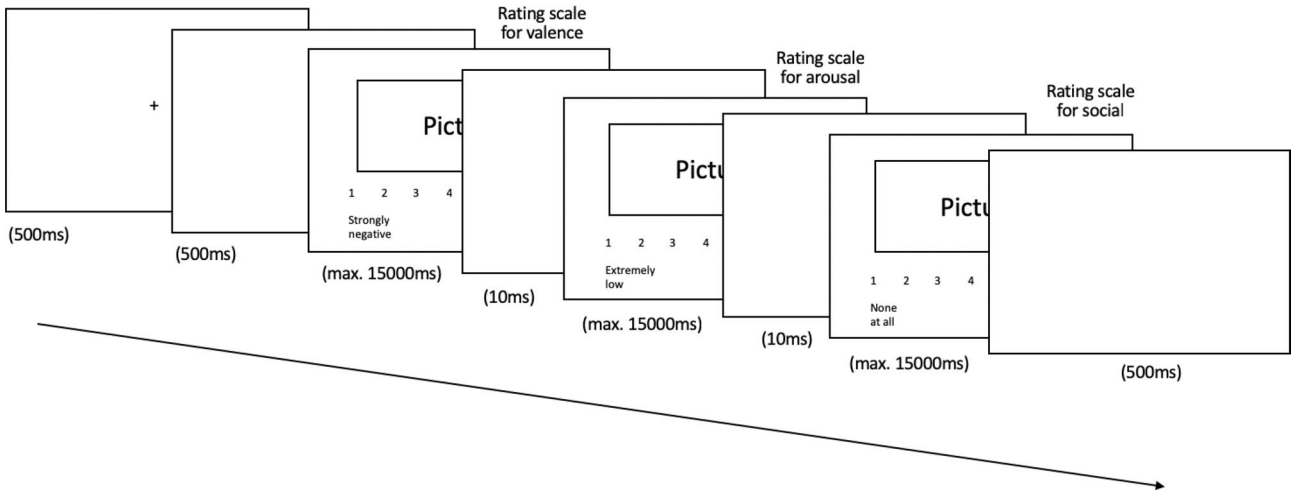

Fig. 2 A graphic overview of the trial design for the picture-rating task

Word-Rating Task

Participants were shown a series of words in the same set-up as that used in the picture-rating task above. Participants rated two 9-point rating scales—emotional valence (from 1 = strongly negative, to 9 = strongly positive) and arousal (from 1 = extremely low, unaroused, to 9 = extremely high)—according to how each word made them feel, following the method used by Warriner et al. (2013). An option for *"I don't know this word"* was provided to ensure that participants did not guess the ratings of the given word if it was unfamiliar to them. Participants took about 32 min on average to complete this task.

The two tasks were administered individually, and the order of tasks was counterbalanced across participants. For each task, participants were given written information about the task and verbally instructed by the experimenter (first author). Next, they were given a laptop computer (14-inch screen) and underwent practice trials while the experimenter observed and provided feedback to ensure that they understood the task. Participants were encouraged to employ the full range of scale values provided. After completing the practice trials, participants continued with test trials and no further feedback was provided to them. This study was approved by the Institutional Review Board of the National University of Singapore.

Results

Preliminary Analyses

The collected data was first examined for nil responses and *"I don't know"* responses. Word stimuli for which 30% or more participants indicated that they did not know the word were removed (Taikh et al. 2015), leading to the exclusion of two words ('ennui' and 'blasé'). In total, missing data accounted for 1% or less of the datapoints in each rating scale in the final dataset of pictures ($N = 203$) and words ($N = 201$). Next, a procedure similar to Schock et al. (2012) was used to ensure reliability in participants' ratings. Each participant's data on every scale was correlated to the average ratings of the remaining participants on the respective scale. Then, from the set of correlation coefficients obtained, means and standard deviations were calculated for each scale in order to identify outliers, defined as more than two *SD*s away from the mean. One participant's data fell more than two standard deviations below the mean for valence ratings on the picture-rating task and was removed from further analyses on this scale. No other participants' data fell below the calculated cut-offs. Lastly, we conducted internal reliability analyses on each rating scale and obtained strong internal reliability on both the picture task ($\alpha_{valence} = 0.95$; $\alpha_{arousal} = 0.78$) and the word task ($\alpha_{valence} = 0.89$; $\alpha_{arousal} = 0.65$). Hence the data were retained for further analyses.

Table 3 Pearson r Correlations between ASD and TD Ratings

	Pictures	Words	Difference
Valence	0.961**	0.915**	$z=0.72$, $p=0.472$
Arousal	0.914**	0.618**	$z=-1.55$, $p=0.121$

**$p<0.01$

Analysis 1: Correlations Between ASD and TD Ratings

Mean ratings of pictures and words by the ASD participants were correlated with TD norms to examine how similarly the two groups performed on the emotional processing tasks. All four ASD-TD correlations were close to perfect, with that for arousal ratings on word stimuli being the exception, albeit still strong (see Table 3). This indicated that for both the picture and word emotional processing tasks, adults with ASD rated valence and arousal similarly to TD adult norms.

Analysis 2: Effect of Valence Conditions on Mean Ratings by ASD and TD Groups

As the correlational analyses above tested systematic differences in relative rather than absolute ratings, and collapsed all items across positive, neutral and negative conditions, we next conducted item-level analyses to examine how valence conditions influenced ratings by ASD and TD groups. We conducted a mixed 2 × 3 ANOVA with group (ASD vs. TD) as the within-factor and valence condition (negative vs. neutral vs. positive) as the between-factor. The groups' mean ratings by conditions are provided in Table 4. To facilitate this analysis, valence cut-off ratings for the PiSCES pictures were applied to the 9-point scale in Warriner et al. (2013) study (see Appendix Table 6 for cut-off ratings).

The analysis for valence of picture stimuli revealed a significant interaction effect between group and valence, $F(2, 200)=45.09$, $p<0.001$, $\eta_p^2=0.31$. Simple effects analyses showed that the ASD group rated negative pictures less negatively [$t(56)=5.61$, $p<0.001$], neutral pictures more positively [$t(71)=10.20$, $p<0.001$], and positive pictures less positively than did the TD group [$t(73)=-4.15$, $p<0.001$] (Fig. 3a). The main effects of group [$F(1,200)=48.30$, $p<0.001$, $\eta_p^2=0.20$] and valence

Table 4 Mean valence and arousal ratings by emotional conditions

	ASD						TD					
	Negative		Neutral		Positive		Negative		Neutral		Positive	
	M	*(SE)*	*M*	*(SE)*	*M*	*(SE)*	*M*	*(SE)*	*M*	*(SE)*	*M*	*(SE)*
Pictures												
Valence	2.47	(0.08)	4.33	(0.07)	5.61	(0.07)	2.11	(0.07)	3.99	(0.06)	5.77	(0.06)
Arousal	4.75	(0.10)	3.58	(0.09)	4.67	(0.09)	4.77	(0.15)	2.95	(0.13)	4.92	(0.13)
Words												
Valence	3.45	(0.10)	5.28	(0.09)	6.79	(0.09)	2.62	(0.09)	5.01	(0.08)	7.29	(0.08)
Arousal	4.21	(0.12)	4.00	(0.11)	5.71	(0.11)	5.53	(0.11)	4.24	(0.10)	5.66	(0.10)

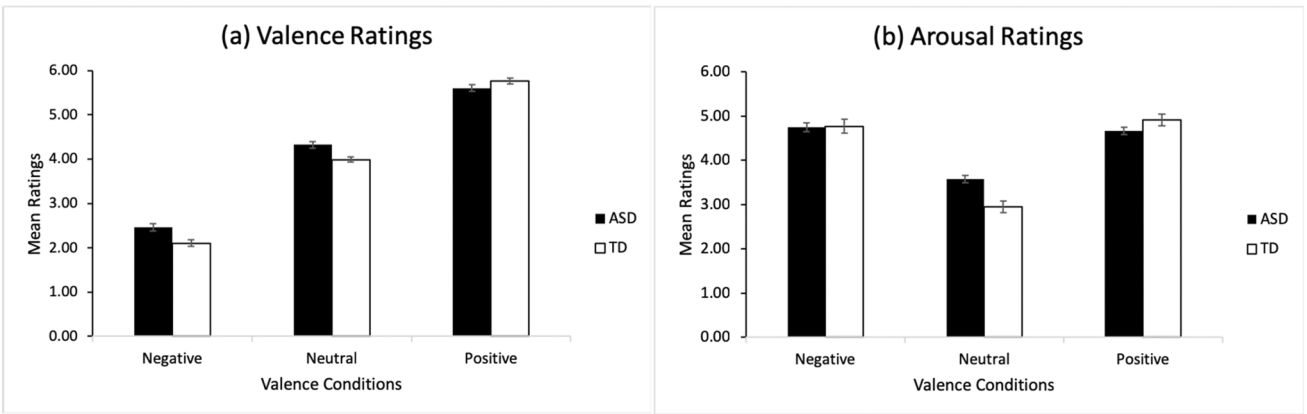

Fig. 3 Mean ratings of ASD versus TD groups on picture-rating task

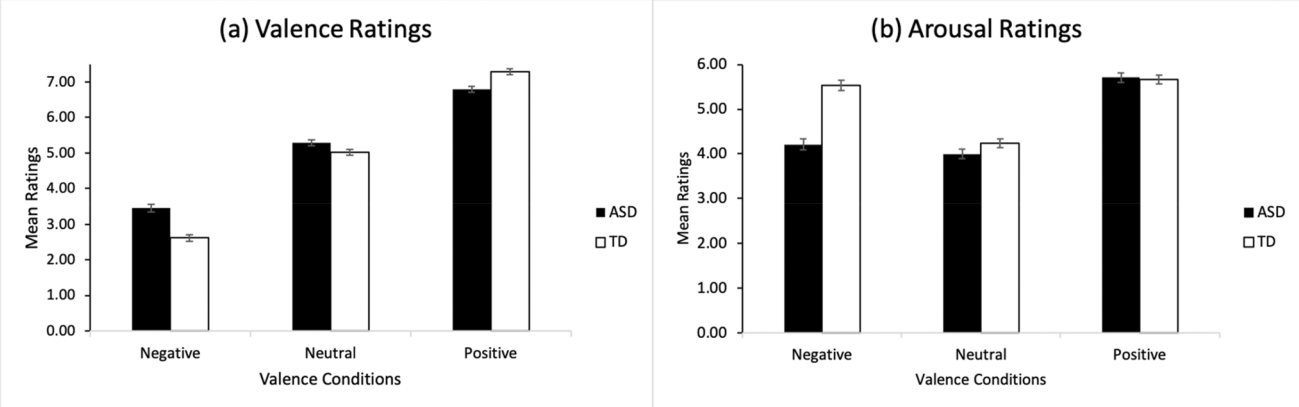

Fig. 4 Mean ratings of ASD versus TD groups on word-rating task

conditions [$F(2,200) = 623.44$, $p < 0.001$, $\eta_p^2 = 0.86$] were significant, but were qualified by the interaction effect.

For arousal ratings of pictures, a significant interaction effect was also found, $F(2, 200) = 38.69$, $p < 0.001$, $\eta_p^2 = 0.28$. The ASD group rated neutral pictures as more arousing [$t(71) = 9.37$, $p < 0.001$] and positive pictures as less arousing than TD group [$t(73) = -3.32$, $p = 0.001$] (Fig. 3b). The two groups rated negative pictures similarly in arousal [$t(56) = -0.26$, $p = 0.798$]. Significant main effects of group, $F(1,200) = 7.34$, $p = 0.007$, $\eta_p^2 = 0.035$, and valence condition, $F(2,200) = 65.81$, $p < 0.001$, $\eta_p^2 = 0.40$, were qualified by the interaction effect.

The analysis for valence of words revealed a significant interaction effect between group and valence, $F(2, 198) = 67.14$, $p < 0.001$, $\eta_p^2 = 0.40$. Similar to the pattern of results found for picture valence above, the ASD group rated negative words [$t(57) = 8.62$, $p < 0.001$] and neutral words [$t(70) = 3.53$, $p = 0.001$] less negatively, and positive words less positively than did the TD group [$t(71) = -7.05$, $p < 0.001$] (Fig. 4a). Significant main effects were found for both group, $F(1,198) = 18.62$, $p < 0.001$, $\eta_p^2 = 0.09$, and valence, $F(2,198) = 639.60$, $p < 0.001$, $\eta_p^2 = 0.87$, but were qualified by the interaction effect above.

The analysis for arousal of words also found a significant interaction effect, $F(2, 198) = 48.70$, $p < 0.001$, $\eta_p^2 = 0.33$. The ASD group rated negative [$t(57) = -11.65$, $p < 0.001$] and neutral words [$t(70) = -2.47$, $p = 0.02$] as less arousing than the TD group, while there was no significant difference in arousal ratings for positive words [$t(71) = 0.52$, $p = 0.605$] (Fig. 4b). The main effects of both group [$F(1,198) = 75.98$, $p < 0.001$, $\eta_p^2 = 0.28$] and valence condition [$F(2,198) = 73.85$, $p < 0.001$, $\eta_p^2 = 0.43$] were significant but qualified by the interaction effect, as described.

Discussion

In this brief report, we present a pilot study examining emotional processing abilities in adults with ASD using two emotion-rating tasks found in the TD literature, one task involving pictures only and the second involving words only. The study also compared performance within each task by valence, to determine relatively intact and impaired aspects of emotional processing in adults with ASD. The results from this pilot study and their implications for future research are discussed below.

Near-Normative Performance in Emotional Rating Tasks

The present study found that adults with ASD rank-ordered emotional picture and word stimuli similarly to TD adults on both valence and arousal dimensions, suggesting that certain aspects of their emotional processing may be intact. Our findings are consistent with Wilbarger et al. (2009) study that reported similar performances by ASD and TD groups when asked to rate the valence and arousal of emotional picture stimuli, but contradicts findings by Trimmer et al. (2017) and Krüger et al. (2018) who reported poorer performance by individuals with ASD asked to rate the valence of videoclips. Although participants in our study and Krüger et al.'s study were both asked to rate the valence of emotions depicted in images, the two studies yielded divergent outcomes. It may be that static images are easier to process than dynamic scenes such as videoclips, as individuals with ASD may have difficulty with complex information-processing particularly in relation to social tasks such as rating emotions (Minshew and Goldstein 1998). To the best of our knowledge, our use of a word-rating task to assess emotional processing in individuals with ASD is novel. The high ASD-TD correlations reported in this pilot study suggest that adults with ASD were able to perform the task and

this provides a new methodological tool for studying emotions in ASD in future.

Emotional Processing Less Impaired than Previously Reported

As presented earlier, previous findings are mixed on emotional processing of words and pictures using non-ratings tasks by adults with ASD. Our study's findings are in line with the general finding of studies by Tang et al. (2019) and South et al. (2008) that adults with ASD perform at a normative level when compared with TD adults. However, our findings are inconsistent with other studies which found that adults with ASD deviated from TD adults in performance (Deruelle et al. 2008; Gaigg et al. 2009). Importantly, these studies used different paradigms to ours, which might account for some of the discrepancy in results. Further, while emotional judgments were reportedly impaired when participants with ASD were required to label emotions in stories and pictures (e.g., Bodner et al. 2015; Boraston 2008), our study using ratings tasks suggests that emotional judgment in ASD may not be as impaired as previously indicated using other paradigms. Our findings here support Lartseva et al.'s (2015) argument that emotional processing in ASD may deteriorate when presented in some paradigms such as memory or discourse tasks.

Potential Role of Language in Emotion Tasks

The strong ASD-TD correlations for valence in both word- and picture-rating tasks ($r > 0.91$ for both) indicate that the use of language in the emotion-processing task did not impact performance in this study. One reason may be that the present sample comprised individuals with average language abilities. Another reason could be that our word-rating task (specifically, a receptive language task using single words) did not impose a high demand on language-processing. In prior studies, adults with ASD showed no impairments in some emotional tasks involving single words (Lartseva et al. 2014; South et al. 2008), whereas impaired performance have been reported in other emotional tasks involving sentences (Beversdorf et al. 1998) and short stories (Bodner et al. 2015). We suggest that the extent to which language is implicated in prior emotion studies may have partially contributed to the mixed findings on emotional processing abilities in participants in ASD, as well as the language abilities of the study samples. Moreover, Lartseva et al. (2015) commented that processing of emotional language might deteriorate when individuals with ASD were asked to process such language in memory paradigms, automatic information processing and in discourse and reasoning. Further experiments using tasks with varying levels of language difficulty will be needed to better understand the role of language on emotional processing in ASD.

Arousal Modulation in Adults with ASD

Out of the four rating dimensions tested, adults with ASD were least similar to TD norms on ratings of word arousal. Specifically, the ASD group reported lower arousal to negatively-valenced words. This is consistent with Lartseva et al. (2014) finding of atypical responses to negative words and may suggest a specific disparity in emotional processing of negative valence in ASD. Even among the TD individuals from whom the norms for the English lemmas were collected, the correlations between individuals' ratings were weaker for arousal than for valence (Warriner et al. 2013), suggesting that the dimension of arousal may be more subjective to the individual. Additionally, difficulties in arousal modulation in individuals with ASD have been reported (Dichter and Belger 2008; Orekhova and Stroganova 2014), which may partially explain the participants' poorer performance in the word arousal rating task when asked to monitor and report their own arousal response to the word stimuli, as opposed to the picture task where they were asked to rate the arousal level of the characters.

Adults with ASD Show a Restricted Range of Valence Response Ratings

This study also revealed subtle differences in the perception of emotion between ASD and TD groups. In terms of valence, the adults with ASD tended to rate positive stimuli less positively, and negative stimuli less negatively than the latter, that is, they tended to use a narrower range of the valence scale than TD adults. In other words, the adults with ASD perceived or experienced a more limited range of valence than TD adults. This is consistent with Trimmer et al. (2017) finding that adults with ASD show dampened mood (i.e., reported less negative mood following distressing videos) than TD controls. The authors suggest that this could be a result of alexithymia—a condition commonly co-occurring with autism that is characterized by difficulties in processing one's own feelings (Nemiah et al. 1976), and has been associated with dampened responses to emotional facial stimuli (Kano and Fukudo, 2013). Alternatively, this tendency could also be related to the reportedly diminished amygdala functioning in ASD which reduces activation in response to emotional stimuli (Corbett et al. 2008). Finally, it could simply be due to a decreased understanding of the task by the current participants.

The above theories warrant further investigation, but for now the answer to whether adults with ASD display an impairment in emotional processing is evidently less

straightforward than it may appear. Their ability to rank-order stimuli similarly to TD individuals indicates that they are able to perform at a level better than prior studies suggest, and yet their use of a narrower range of valence suggests that their perception of and response to emotion remains atypical compared to TD individuals.

Limitations

Due to the small sample size in this pilot study, we were unable to examine gender differences in emotional processing or to draw definitive conclusions for theory based on our current findings. Another limitation is that we did not include measures for alexithymia in the sample group or use physiological measures for arousal, which would have provided more insight into dampened valence and arousal ratings by adults with ASD. These are interesting directions for future inquiry that may explain the mixed findings in the literature and extend our knowledge of emotional processing skills and deficits in ASD.

In closing, the present study provides preliminary evidence highlighting the need for a more nuanced understanding of emotional processing in ASD. Future researchers may consider the potential effects of task and language demands, as well as valence conditions and arousal levels, on emotional processing. We suggest that the participants' consistent use of a more restricted range on the valence scale compared to TD norms, and atypical arousal ratings under certain conditions, may indicate alexithymia, atypical amygdala functioning, or ASD-characteristic difficulties with arousal modulation. These areas warrant further research. Finally, our findings have practical implications for ASD intervention, including the importance of expanding the understanding and perception of emotions by people with ASD, and exploring their understanding of emotional words, particularly negatively-valenced words, which may have an impact on their communication effectiveness.

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Author Contributions The study was conceptualized and designed by TW, MY and ET. Material preparation, data collection and analyses were conducted by TW, supervised by MY and ET. Additionally, TO supported diagnostic testing of participants for autism spectrum disorder. The first draft of the manuscript was written by TW and revised by ET and MY, with comments from TO and CA. All authors read and approved the final manuscript.

Appendix

See Tables 5 and 6

Table 5 List of word stimuli (N = 203, taken from Warriner et al. 2013) shown in order of increasing valence rating, from 'Strongly negative' to 'Strongly positive'

Suicide	Stink	Corridor	Detail	Grin
Cancer	Rat	Hammer	Rock	Devoted
Suffocate	Destruction	Blasé	Lion	Dollar
Torture	Beggar	Iron	Unit	Glory
Slaughter	Bastard	Aloof	Alien	Talent
Infection	Gun	Cannon	Medicine	Freedom
Syphilis	Grenade	Metal	Runner	Intimate
Disaster	Weary	Icebox	Book	Cute
Abuse	Mangle	Storm	Trumpet	Leader
Mutilate	Tamper	Stove	Skyscraper	Profit
Depression	Listless	Taxi	Horse	Food
Drown	Lump	Hydrant	Village	Rescue
Misery	Absurd	Rattle	Chance	Car
Disloyal	Skull	Barrel	Foam	Admired
Dead	Vanity	Cabinet	Nurse	Pretty
Distressed	Solemn	Ink	Clouds	Outstanding
Poison	Cellar	Inhabitant	Field	Spring
Hatred	Shadow	Scissors	Tree	Gift
Burial	Corner	Pig	Blond	Triumph
Maggot	Muddy	Rain	Plane	Christmas
Demon	Alley	Machine	Nice	Wedding
Pain	Bus	Ennui	Mind	Birthday
Detest	Fur	Aggressive	Space	Party
Discomfort	Obey	Utensil	Vigorous	Achievement
Stench	Bandage	Clock	Lake	Fame
Devil	Lightning	Umbrella	Beverage	Aroused
Humiliate	Errand	Tank	Thankful	Confident
Fearful	Slush	Context	Kids	Engaged
Insult	Dark	Concentrate	Decorate	Joke
Defeated	Thermometer	Pencil	Infant	Terrific
Agony	Square	Cork	Greet	Lucky
Disgusted	Rough	Hard	Agreement	Promotion
Robber	Glass	Headlight	Child	Happy
Flabby	Pamphlet	Lawn	Snow	Treasure
Fraud	Kerosene	Patent	Exercise	Victory
Venom	Board	Finger	Learn	Comedy
Vandal	Stomach	Patient	Capable	Fun
Hostile	Odd	News	Lively	Affection
Fever	Curtains	Time	Prestige	Laughter
Mistake	Hairdryer	Reverent	Bath	
Blister	Tease	Lamp	Impressed	

Table 6 Cut-off ratings for valence conditions

Condition	Pictures from PiSCES Teh et al. (2018)		Words from Warriner et al. (2013)	
	Valence ratings (scale of 1–7)	n	Valence ratings (scale of 1–9)	n
Negative	1.0 to < 3.5	57	1.0 to < 4.33	58
Neutral	3.5 to < 4.5	72	4.33 to < 5.67	71
Positive	4.5–7.0	74	5.67–9.0	72

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