Journal of Autism and Developmental Disorders
https://doi.org/10.1007/s10803-018-3712-9

ORIGINAL PAPER

Task Dependency When Evaluating Association Between Facial Emotion Recognition and Facial Emotion Expression in Children with ASD

Andrea Trubanova Wieckowski[1] · Deanna M. Swain[1] · A. Lynn Abbott[2] · Susan W. White[3]

Abstract
The impact of facial emotion recognition (FER) deficits on facial emotion expression (FEE) during interaction with a novel computerized system was investigated in children with ASD ($n = 20$), in comparison to typically developing (TD) peers ($n = 20$). Although there was not clear evidence of impaired FEE, children with ASD showed more atypical FEE. In children with ASD, better FER predicted better FEE when the participants were asked to express a labeled emotion ($t(18) = -2.75$, $p = .01$, $d = 1.24$). The stronger relationship between FER and FEE in children with ASD, relative to controls, suggests that intervention targeting social communication deficits might have maximal effect when both processes are considered.

Keywords Facial emotion recognition · Facial emotion expression · Social communication · Autism spectrum disorder

Introduction

Impairments with facial emotion recognition (FER) and expression (FEE) manifest across a range of psychiatric disorders, including eating disorders (FER: e.g., Zonnevijlle-Bender et al. 2002; FEE: e.g., Rhind et al. 2014), externalizing disorders (FER: e.g., Aspan et al. 2013; FEE: e.g., Keltner et al. 1995), and depression (FER: e.g., Jenness et al. 2014). Difficulty in these processes impacts communication and social interaction (Nuske et al. 2013). Social impairments are considered hallmark symptoms of autism spectrum disorder (ASD; American Psychiatric Association 2013) and are, at least partially, believed to be rooted in FER and FEE deficits.

The difficulties with FER that characterize children with ASD appear early in childhood (e.g., Rump et al. 2009). Perhaps the most robust and consistent finding across studies is that deficits for recognition of anger, fear, and surprise are common in ASD (Lozier et al. 2014). FER impairments have been seen with both static and dynamic stimuli (e.g., Evers et al. 2015). Although adolescents and adults with ASD often do not show impairment in recognizing basic, prototypical emotions (Capps et al. 1992; Grossman et al. 2000), they show difficulties in FER when expressions are more subtle or complex, or when stimuli are presented for short durations (Humphreys et al. 2007). In addition, prior research has demonstrated the importance of stimulus type when assessing FER in children with ASD. For example, youth with ASD have shown similar, and at times better, ability to recognize emotions compared to typically developing peers when emotions are presented with cartoon stimuli (Brosnan et al. 2015). However, the same individuals showed more difficulty compared to non-ASD peers when the emotion was presented with human stimuli (Brosnan et al. 2015). Stimulus type therefore is critically important to explore when assessing FER in youth.

Compared to FER, there is more limited research on FEE in ASD. This is somewhat surprising since FEE impairment is indicative of possible diagnosis of ASD; indeed, FEE is one of the abilities evaluated through the Autism Diagnostic Observation Schedule-Second Edition (ADOS-2; Lord et al. 2012), the most commonly used tool for diagnosis of ASD. Studies have indicated that children with ASD demonstrate

This study was conducted at Virginia Tech.

✉ Andrea Trubanova Wieckowski
atruban@vt.edu

[1] Department of Psychology, Virginia Tech, Blacksburg, VA 24061, USA

[2] Bradley Department of Electrical and Computer Engineering, Virginia Tech, Blacksburg, VA 24061, USA

[3] Department of Psychology, The University of Alabama, Tuscaloosa, AL 35401, USA

Published online: 01 September 2018

diminished, and perhaps atypical, FEE. Individuals with ASD display fewer nonverbal expressions of affect (Kasari et al. 1990; Shalom et al. 2006), and their facial expressions are often described as flat, inappropriate, or peculiar (Langdell 1981; Yirmiya et al. 1989). Loveland et al. (1994) found that adults with ASD produced fewer recognizable expressions, compared to adults with Down syndrome, during a task that required them to produce named emotional expressions, and these expressions were noted to be "mechanical" (i.e., emotion was expressed in a stereotyped way) or "bizarre" (i.e., emotion was unrecognizable or uncodable), suggesting difficulty with ability to produce expressions in ASD. Atypical FEE can make social interaction and communication challenging, even when verbal abilities may be intact.

Since both FER and FEE are critical for social interaction, and children with ASD show impairments in both processes, understanding the relation between the two processes may be informative, and may help to maximize the impact of intervention targeting social communication. However, most clinical research in this area has addressed FER only (e.g., Harms et al. 2010) and no studies, to our knowledge, have explored the relationship between these two processes in individuals with ASD. While prior studies have found a relationship between FER and FEE in populations outside of ASD (e.g., Ricciardi et al. 2017 explored this correlation in individuals with Parkinson's), this relationship has been unexplored in children with ASD.

The purpose of the current study is to explore FER ability and FEE ability in children with and without ASD. Consistent with the prior studies, which have largely examined FER and FEE separately in individuals with ASD, we hypothesize that participants with ASD will show lower FER ability as well as lower FEE ability compared to typically developing participants, both in terms of accuracy as well as quality (i.e., atypicality). We expected the ASD sample to show more atypical expression, compared to the typically developing children. Given prior findings showing a link between FER and FEE in populations outside of ASD, we also hypothesized that ability to recognize emotion (i.e., high vs low FER score) will have a strong positive correlation with the ability to express emotion. More specifically, for children with ASD as well as typically developing (TD) children, higher FER accuracy was expected to be related to higher FEE accuracy. As an exploratory aim, we examined the effect of stimulus type (i.e., cartoon face, human face, audio-visual track without a face) on the relationship between FER and FEE.

Method

Participants

Participants included children with ASD ($n=20$) and without ASD ($n=20$) aged 9–12 years without co-occurring intellectual disability, as assessed by the Wechsler Abbreviated Scale of Intelligence (WASI-2; Wechsler 2011). Children in the ASD group (18 males) all had prior clinical diagnoses of ASD, which were confirmed in this study by the ADOS-2 (Lord et al. 2012). The children in the TD group (14 male) had never received any clinical diagnoses, based on parent report. Participant characteristics are reported in Table 1.

Measures

Facial Emotion Expression Training (FEET; Aly et al. 2018)

An interactive, computer-assisted program, FEET was designed to train appropriate emotion expression. In the present study, the participants did not receive FEET as intervention, but rather to determine 'proof of concept' (i.e., that FEET could detect the facial expressions). As such, each child participated in a single FEET session. The system uses Microsoft Kinect technology to capture a standard RGB video and a registered set of 3D data points associated with important features of the face. Microsoft provides a standard software package that automatically detects the facial features. Automated FER was developed for extraction of those features using machine-learning techniques, to determine the emotion that the child was making and to provide corrective feedback in the moment. For more information about the FEET system, refer to Aly et al. (2018). The system also saves RGB video frames of the participant's face to allow for independent coding of the emotions after the session.

Table 1 Demographic data

	ASD ($n=20$)	TD ($n=20$)	χ^2/t
Gender (male)	18	14	2.50
Race			5.03
White	16	17	
Black	2	0	
Latino	1	0	
Asian/other	1	2	
NA	0	1	
Age (months)	122.50	129.75	1.76
IQ	100.55 (13.96)	118.15 (11.53)	4.35**

TD typically developing, *ASD* autism spectrum disorder

*$p<.05$; **$p<.01$

While interacting with FEET, the child is asked to express the emotion that is presented in an audio/video, with the instruction of "With your face, show what I am feeling." As shown in Fig. 1, the stimuli progress from simple animated cartoon faces expressing an emotion (Level 1), to recordings of a child actor expressing an emotion (Level 2), and finally to scenes, without faces, depicting emotionally laden situations (e.g., lightning at night shown with scary noises in the background; Level 3). This progression was chosen given prior studies showing children with ASD performing similar to TD peers on recognition of animated stimuli, while showing relative impairment in recognition of human faces (e.g., Brosnan et al. 2015). In addition, the progression included scenarios with non-facial stimuli, to explore generalization of FEE outside of potential facial mimicry. One stimulus per emotion is presented for each of the levels and all stimuli are dynamic videos. The program automatically progresses the child through the levels, irrespective of the user's response. In addition, within each level, the intensity of the depicted emotion increases (e.g., smile gets bigger for happy expression) in order to provide an aid to the child, within each level. The child also receives feedback in real time, either a congratulatory message or corrective feedback of "That's not quite right. Try again." After the three levels in which the children were asked to express the emotion presented, the system assessed FER using familiar stimuli (i.e., cartoon images from Level 1). More specifically, children were prompted to verbally tell the examiner what emotion was expressed by picking from one of the four options (i.e., anger, happiness, neutral, fear).

Facial Expression Photographs

Participants' ability to make basic facial emotional expressions were collected at the beginning of the study. Each participant was asked to make the six basic emotions (i.e., anger, happiness, sadness, fear, disgust, surprise) and a neutral expression. The child was asked to hold the expression while the evaluator took a photograph of the child's face (i.e., from shoulders to top of the head). The task measures children's ability to volitionally produce a labeled expression without a model or corrective feedback.

NEPSY-II Facial Affect Recognition Test (Korkman et al. 2007)

The facial affect recognition (AR) test of the Developmental Neuropsychological Assessment (NEPSY-II) assesses ability to recognize common facial expressions (i.e., anger, happiness, sadness, fear, disgust, and neutral) using static, colored images. Children are presented with different tasks, including selecting two photographs of faces with the same affect from 3 to 4 photographs, selecting one of the four faces that depicts the same expression as a face at the top of the page and, after briefly shown a face, from memory, selecting two photographs that depict the same affect as the face previously shown. The task yields age-based standard scores with a mean of 10 and standard deviation of 3, with lower scores indicating worse FER ability. Within our sample, internal consistency (coefficient alpha) across the scaled score and errors for each emotion was 0.703.

Procedure

The sessions took place at a university-affiliated assessment clinic. All participants completed one session, after providing consent (parent) and assent (youth). Afterward the youth were administered the WASI-2, ADOS-2, and several questionnaire measures, while the parent completed the demographic questionnaire and several surveys not analyzed for the purposes of this study.

Two undergraduate research assistants, who were naïve to the group assignment of the participants, coded the participants' expressions from the photographs and from the videos captured by the FEET program. The training for behavior coding included didactic education about emotions, group

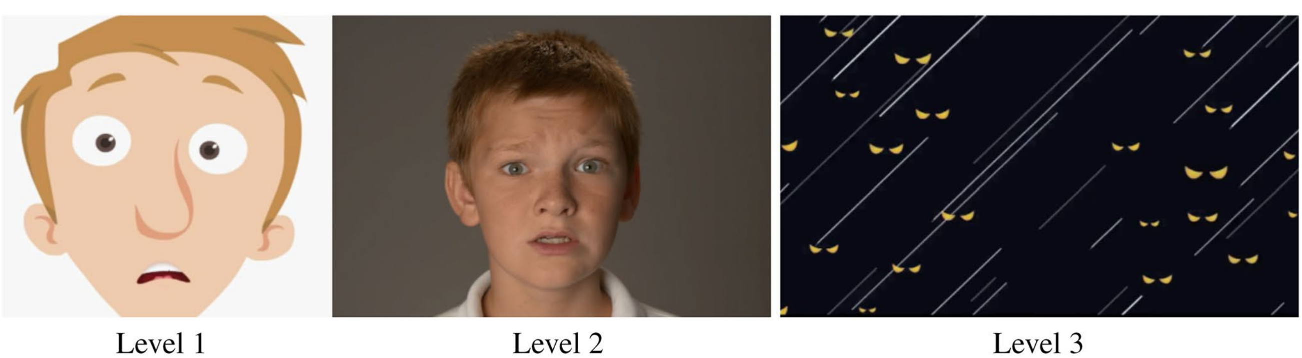

Fig. 1 Single frames from sample video stimuli for scaffolded levels depicting fear. Level 1 = cartoon character; Level 2 = human expression; Level 3 = scene eliciting emotions

co-coding, and discussion of selected training stimuli to ensure consistency. Coders needed to establish at least 80% agreement, on all code types (see below), with the trainers (i.e., PhD clinical psychologist and Master's level graduate student) to be deemed reliable. First, the coders viewed the entire series of still photographs that comprised a trial (range from 57 to 430). Then, coders noted an onset of an emotional expression at a specific frame (e.g., frame 131 of 230 total frames). Finally, a series of 30 total frames (i.e., 10 before and 20 after a specific frame) were provided to the FEET training system for the generated code. Coders assigned an emotion label to each video from the six basic emotions: happiness, sadness, fear, surprise, disgust, anger, or neutral expression. Coders were instructed to select their emotion label from the first onset of a clear emotion presentation. If multiple emotions were expressed, the coder only provided codes for the first emotion shown. In addition, coders assigned a rating of how atypical the expression was, from 0 (completely normal, not at all atypical) to 2 (very atypical). These atypical ratings were adapted from Loveland et al. (1994) to identify mechanical and bizarre facial expressions. For example, a rating of a "0" was assigned if an emotion was recognizable and typical in nature (i.e. no exaggerated or unusual features), a "1" if the expression was recognizable but a poor example because of some distortion or unusual feature (i.e., wrinkled nose for angry), and a "2" if the expression is obviously odd, stereotyped, or mechanical in nature. Half of the videos and all photographs were co-coded in order to establish inter-rater agreement. When disagreement occurred, a third rater, one of the trainers aware of assignment, assigned the final code. For the still photographs, the trainer resolved 22% of total photographs (i.e., 60 of 266). For the FEET videos, the trainer resolved 30.48% of total videos (i.e. 218 of 715). There was moderate agreement in assigned emotion codes between the two independent raters, $\kappa = 0.639$ (95% CI 0.600–0.678), $p < .001$, for the co-coded videos and substantial agreement between raters on photographs, $\kappa = 0.737$ (95% CI 0.671–0.803), $p < .001$.

Data Analyses

Data were analyzed with IBM SPSS Statistics Version 24. Descriptive statistics were computed for all demographic variables and data were checked for outliers and highly influential data points using the boxplot in SPSS. Independent samples *t* tests were conducted to explore group differences for all demographic variables as well as FER. Due to small cell sizes and non-independence of the dependent variables, a single overall ANOVA was not able to be run (Tabachnick and Fidell 2012). Instead, for each level of FEE, a two-way Analysis of Variance (ANOVA) was run to explore the relationship between group (2 levels: ASD vs TD), FER (2 levels: high FER and low FER) and the interaction of group and FER on FEE accuracy and atypicality. Finally, Pearson correlations were run to compare the demographic and independent variables in order to determine covariates. A significance level of 0.05 was used for statistical tests. Based on the power analysis for ANOVA main effects, we had sufficient power (0.799) to detect a large (Cohen's $f = 0.40$) effect, for a two-tailed test ($\alpha = 0.05$). Given the preliminary nature of the study, we include the effect sizes in addition to the significance testing.

Results

Group Differences

Descriptive Statistics

Descriptive statistics were computed for all demographic variables to characterize the sample (Table 1). Outliers were identified within the TD group for atypical expressions within Level 1 ($n = 2$) and Level 2 ($n = 1$). The groups did not differ significantly in age, $t(38) = 1.76$, $p = .09$, sex, $\chi^2(1) = 2.50$, $p = .11$, or race, $\chi^2(4) = 5.03$, $p = .41$. There was a group difference in IQ, $t(38) = 4.35$, $p < .01$. IQ was not, however, statistically correlated to any FER or FEE variables in the total and ASD groups. However, in the TD group, IQ was positively correlated to percentage of correct FEE during Level 1 (i.e., cartoon characters). Regardless, IQ was included as a covariate for all analyses described below and did not yield discrepant findings.

Facial Emotion Recognition Accuracy

There was a significant group difference of medium effect in participants' ability to identify emotions, based on the NEPSY AR test, ($t(38) = 2.08$, $p = .04$, $d = 0.66$). The TD group scored higher on the task ($M = 12.00$, $SD = 1.97$) compared to the ASD group ($M = 10.50$, $SD = 2.54$).

Effect of Group and FER Ability on FEE Accuracy

A 2 (group: TD vs ASD) × 2 (FER: low vs high) ANOVA examining FEE accuracy for photograph stills revealed no main effects of group ($F(1,39) = 0.39$, $p = .54$, partial $\eta^2 = 0.01$) or FER ($F(1,39) = 0.46$, $p = .41$, partial $\eta^2 = 0.02$). Although not significant, there was an interaction effect of medium size between group and FER on FEE ($F(1,39) = 3.33$, $p = .07$, partial $\eta^2 = 0.08$). For the ASD group, FER had a significant effect on FEE; those with high FER showed significantly higher FEE than those with low FER ($t(18) = -2.75$, $p = .01$, $d = 1.24$). For the TD group, however, high versus low FER did not significantly differ in FEE ability ($t(18) = 0.59$, $p = .56$, $d = 0.31$, see Fig. 2).

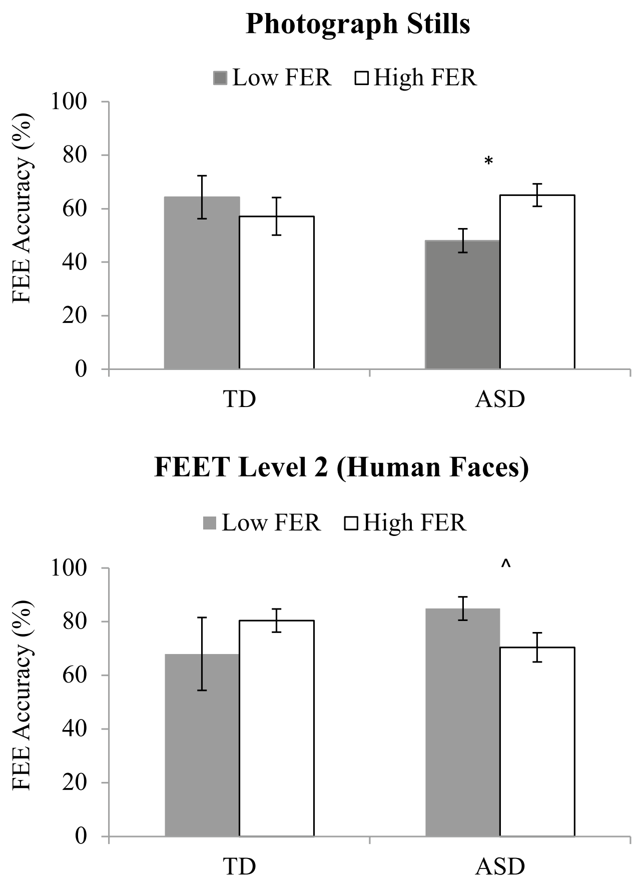

Fig. 2 FER accuracy rating in relation to high and low FER for TD and ASD group for photograph stills (top) and Level 2 of FEET (bottom). Significant difference is denoted by *p < .05. ^p < .10

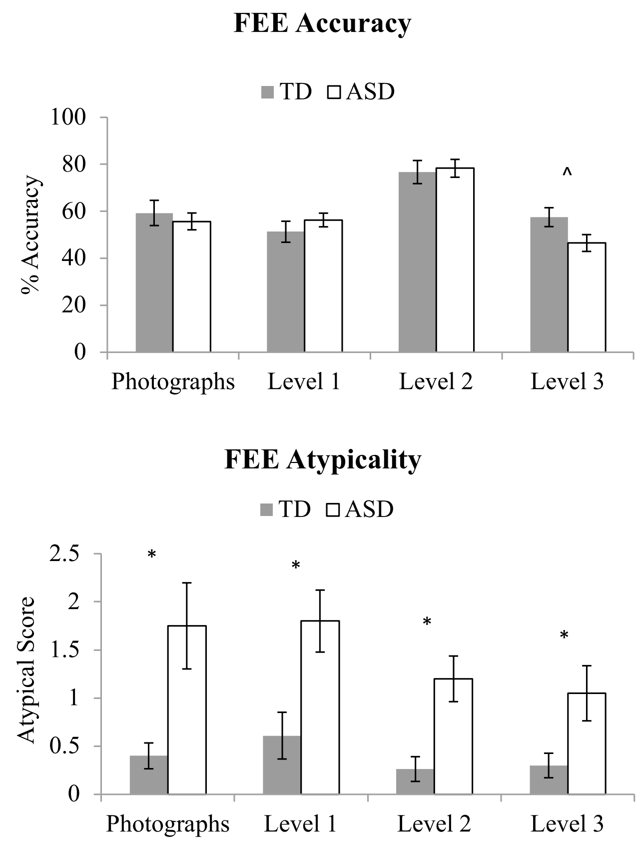

Fig. 3 FEE percent accuracy (top) and FEE atypicality (bottom) for TD and ASD groups. Significant difference is denoted by *p < .05. ^p < .10

A second 2 (group) by 2 (FER) ANOVA examining FEE accuracy for Level 1 (i.e., cartoon faces) yielded no group ($F(1,39) = 1.25$, $p = .27$, partial $\eta^2 = 0.03$) or FER ($F(1,39) = 0.71$, $p = .41$, partial $\eta^2 = 0.02$) main effects. Furthermore, there was not a significant interaction between group and FER on FEE accuracy ($F(1,39) = 0.03$, $p = .86$, partial $\eta^2 < 0.01$).

For FEET Level 2 (i.e., human faces), a 2 × 2 ANOVA revealed no effect of group ($F(1,39) = 0.29$, $p = .59$, partial $\eta^2 = 0.01$) or FER ($F(1,39) = 0.03$, $p = .86$, partial $\eta^2 < 0.01$) on FEE accuracy. However, there was a significant interaction effect between group and FER ($F(1,39) = 4.50$, $p = .04$, partial $\eta^2 = 0.11$). Specifically, as shown in Fig. 2, although not statistically significant following the Bonferroni correction, for the ASD group, higher FER was strongly associated with lower FEE ($d = 0.95$), $t(18) = 2.12$, $p = .05$. For the TD group, however, high versus low FER did not significantly differ in FEE accuracy ($t(18) = -1.13$, $p = .27$, $d = 0.47$; Fig. 2).

A final 2 (group) × 2 (FER) ANOVA examining FEE accuracy for Level 3 (i.e., scenes eliciting emotions) revealed no main effect for FER ability ($F(1,39) = 0.28$, $p = .60$, partial $\eta^2 = 0.01$) and no interaction between group and FER ($F(1,39) = 0.09$, $p = .77$, partial $\eta^2 < 0.01$). Although not significant, there was a medium effect of group on FEE accuracy for Level 3 ($F(1,39) = 2.99$, $p = .09$, partial $\eta^2 = 0.08$; Fig. 3).

Effect of Group and FER Ability on FEE Atypicality

In regard to the amount of atypical expressions for the photograph stills, a 2 (group: TD vs ASD) × 2 (FER: low vs high) ANOVA revealed no effect of FER ($F(1,39) = 0.19$, $p = .67$, partial $\eta^2 < 0.01$) or an interaction between group and FER ($F(1,39) = 1.23$, $p = .28$, partial $\eta^2 = 0.03$). There was, however, a significant group effect on atypical FEE ($F(1,39) = 7.85$, $p = .01$, partial $\eta^2 = 0.18$). Specifically, the ASD group was rated as showing statistically more atypical emotional expressions than the TD group during the photograph stills task (see Fig. 3).

A 2 (group) × 2 (FER) ANOVA examining amount of atypical expressions for Level 1 (i.e., cartoon faces) yielded a main effect for group ($F(1,37) = 6.88$, $p = .01$, partial $\eta^2 = 0.17$) but not for FER ($F(1,37) = 0.23$, $p = .63$, partial $\eta^2 = 0.01$). Specifically, the ASD group displayed more atypicality in facial expression than the TD group during the cartoon faces task (see Fig. 3). There was not a significant interaction between group and FER on FEE atypicality ($F(1,37) = 0.27$, $p = .61$, partial $\eta^2 = 0.01$).

In regard to the amount of atypical expressions for Level 2 (i.e., human faces), a 2 × 2 ANOVA showed no effect of FER ($F(1,38) = 0.30$, $p = .59$, partial $\eta^2 = 0.01$) or an interaction between group and FER ($F(1,38) = 0.07$, $p = .80$, partial $\eta^2 < 0.01$). There was, however, a significant group effect on atypical FEE ($F(1,38) = 10.46$, $p < .01$, partial $\eta^2 = 0.23$). Specifically, the ASD group showed more atypicality in FEE than the TD group during the human faces task (see Fig. 3).

Similarly, a 2 × 2 ANOVA examining the amount of atypical FEE during Level 3 revealed no main effect for FER ($F(1,39) = 0.26$, $p = .62$, partial $\eta^2 = 0.01$) and no interaction effect ($F(1,39) = 0.61$, $p = .44$, partial $\eta^2 = 0.02$). A significant group effect emerged ($F(1,39) = 6.22$, $p = .02$, partial $\eta^2 = 0.15$), demonstrating that the ASD group showed more atypicality in emotional expression than the TD group during the FEET Level 3, which showed no facial model as a referent.

Discussion

As hypothesized, results from our study suggest that children with ASD show decreased FER and FEE ability, along with atypical expressiveness, compared to their typically developing peers. Consistent with prior research, the way FEE was assessed (i.e., requesting a labeled expression versus a reaction to someone else making an expression) greatly impacted the children's performance. In addition, the type of stimulus impacted the relationship between participants' FER and FEE.

Comparing FEE accuracy between groups, we found that children with ASD were just as accurate as their peers when they were asked to make a specific, named emotion. In addition, children with ASD were comparable to TD peers when expressing emotions in response to a facial expression of emotion made by a cartoon or by a human. However, children with ASD were less accurate at expressing the target emotion in response to a scene eliciting an emotion, when the emotion was neither labeled nor modeled. While this difference was not significant, the effect size was medium, indicating an important difference between groups which we may be underpowered to statistically detect. FEE ability appears to deteriorate in children with ASD when facial stimuli are removed or the cues are less obvious. This result is consistent with prior studies which indicate that individuals with ASD rely on rule-based strategy when perceiving facial expression of emotions (e.g., Rutherford and McIntosh 2007). With the absence of faces, children with ASD are not able to rely on the rule-based strategy for emotional perception, resulting in lower accuracy. This result suggests the importance of incorporating more natural, situational (non-facial) scenarios during assessment and treatment of FEE in children with ASD.

In addition, the group difference in atypicality of FEE is fairly robust, as the ASD group was found to show more atypicality in expression across all levels of the stimulus presentations, including during the photographs, Level 1 (cartoon faces), Level 2 (human faces), and Level 3 (scenes eliciting emotions). Given that the raters were naïve to the group condition of the participants, results suggest that even when children with ASD make a "correct" emotion, their expressions are atypical, highlighting the importance of training of natural expressions in response to situations eliciting an emotion. This result is consistent with prior studies suggesting that even when individuals with ASD make accurate expressions, they are rated as more intense and less natural or awkward (e.g. Faso et al. 2015; Grossman et al. 2013). These differences in expressivity have important impacts on children's social interactions. For example, Stagg et al. (2014) asked adults and children who were naïve to children's diagnosis to rate videos of children for expressivity as well as investigated friendship ratings given by typically developing children to the same videos. The authors found that adults rated children with ASD as being less expressive than typically developing children and the child raters found these children with ASD to be lower on all aspects of friendship measures compared to typically-developing children. In addition, Sasson et al. (2017) found that typically-developing observers rated first impression of children and adults with ASD engaging in social behavior to be less favorable compared to controls. These impressions were in turn associated with reduced intention to engage socially with the individuals. The biases, however, disappeared when perceptions were based on conversational content lacking audio-visual cues, suggesting the style was what drove the negative impression of ASD. While other factors likely contribute to the less favorable impressions, these studies together suggest that expression, at least in part, impacts how children with ASD are perceived.

Unlike the results for the group differences, the findings regarding the relationship between FER and FEE are fairly mixed. Contrary to what we predicted, results suggest that FER ability does not broadly effect FEE. Rather, FER appears to relate to FEE only for the ASD participants, and only for certain FEE tasks. Specifically, children with ASD with high FER were significantly higher in FEE, than were those with low FER, when asked to make a specific, labeled but non-modeled emotion (i.e., they were told what emotion to show). However, this effect was not apparent when the stimulus for FEE was visual and more naturalistic. In fact, although the effect was not significant following the correction for multiple comparisons, for the ASD group only, those with high FER had lower FEE ability compared to those with low FER when they were asked to respond to a human face expressing an emotion. The significant relationship found between FER ability level and FEE when asked to make a labeled emotion is in line with our prediction, as greater understanding of emotions is likely to lead to better expression of the emotion. It is interesting, however, that this finding was present only when participants were asked to make a specific, labeled emotion—which is arguably an easier task than showing an unlabeled emotion in response to a fairly vague prompt. The fact that this relationship is not evident across all FEE tasks speaks to the greater similarity between labeling of the emotion (i.e., FER) and expressing a labeled emotion, and highlights the importance of task demands—specifically consideration of the degree to which the task requires understanding of emotion labels versus ability to show emotion via facial expression.

These findings should be considered in light of the study's limitations, of which the primary one is the significant difference in cognitive ability among the TD and ASD groups. The uneven distribution could have influenced our results. However, no participants obtained a score falling in the range of possible intellectual disability. Relatedly, because participants in this study were all relatively cognitively high functioning, generalization of findings to lower functioning or nonverbal populations is limited. In addition, the FEE task in this study assessed children's ability to volitionally produce labeled or prompted emotion, and did not assess children's capability of spontaneously expressing genuine, or felt, emotions. As these abilities likely differ, future studies should explore the relationship between FER and FEE exploring spontaneous expression of FEE. Lastly, although we were powered to detect large effects for our primary analyses, the sample sizes were small across the two groups, limiting our ability to detect small effect sizes as well as use of more sophisticated analytic approaches.

The current study investigated the relationship between FER and FEE in children with and without ASD. The results presented here are consistent with past research (e.g., Kasari et al. 1990; Lozier et al. 2014) showing that children with ASD demonstrate impoverished ability to both recognize and express emotions. Our findings indicate the ability to express an emotion is dependent on task parameters, with children with ASD scoring lower than TD peers when asked to respond to a scene eliciting an emotion. The relationship between recognition and expression is variable and, likewise, somewhat task dependent. Children with ASD who score higher on FER were found to show higher FEE only when asked to express a labeled (named) emotion. The association between FER and FEE, seen only in the ASD group, suggests that intervention targeting nonverbal social communication might have maximal effect if both processes are targeted. The lack of relationship between FER and FEE in TD children, across the tasks, suggests that these two processes are not functionally interconnected, despite conceptual similarity. Construct independence, for both FER and FEE, among typically developing youth is further supported by findings in individuals who are visually impaired from birth who show no impairment in spontaneous facial expression of emotion (e.g., Matsumoto and Willingham 2009) even when they have not seen others express the emotion. Although further research on this topic is needed, our findings suggest that, in children with ASD, neither FER nor FEE develop in the same 'innate' way as they do in neurotypical children. It is possible that FER may be relied upon, perhaps as a compensatory learning strategy, in the service of FEE.

Acknowledgments This project was funded by a Grant from NICHD (R03HD081070; Co-PIs Abbott & White).

Author Contributions ATW participated in the Collected data, performed data analysis and drafted the manuscript. DMS participated in the Collected data, performed data analysis and contributed to writing of the manuscript. ALA Contributed to planning and design of the study and revision of the manuscript. SWW Conceived the study, designed the study, contributed to writing of the draft and revision of the manuscript.

References

Aly, S., Abbott, A. L., Wieckowski, A. T., White, S. W., & Youssef, A. E. (2018). Fast 3D facial expression recognition. Manuscript submitted for publication.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: APA.

Aspan, N., Vida, P., Gadoros, J., & Halasz, J. (2013). Conduct symptoms and emotion recognition in adolescent boys with externalization problems. *The Scientific World Journal*. https://doi.org/10.1155/2013/826108.

Brosnan, M., Johnson, H., Grawmeyer, B., Chapman, E., & Benton, L. (2015). Emotion recognition in animated compared to human stimuli in adolescents with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 45*(6), 1785–1796.

Capps, L., Yirmiya, N., & Sigman, M. (1992). Understanding of simple and complex emotions in non-retarded children with autism. *Journal of Child Psychology and Psychiatry, 33*(7), 1169–1182.

Evers, K., Steyaert, J., Noens, I., & Wagemans, J. (2015). Reduced recognition of dynamic facial emotional expression and emotion-specific response bias in children with an autism spectrum disorder. *Journal of Autism and Developmental Disorders, 45*(6), 1774–1784.

Faso, D. J., Sasson, N. J., & Pinkham, A. E. (2015). Evaluating posed and evoked facial expressions of emotion from adults with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 45*(1), 75–89.

Grossman, J. B., Klin, A., Carter, A. S., & Volkmar, F. R. (2000). Verbal bias in recognition of facial emotions in children with Asperger syndrome. *Journal of Child Psychology and Psychiatry, 41*(3), 369–379.

Grossman, R. B., Edelson, L. R., & Tager-Flusberg, H. (2013). Emotional facial and vocal expressions during story retelling by

children and adolescents with high-functioning autism. *Journal of Speech, Language, and Hearing Research, 56*(3), 1035–1044.
Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in Autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Review, 20*(3), 290–322.
Humphreys, K., Minshew, N., Leonard, G. L., & Behrmann, M. (2007). A fine-grained analysis of facial expression processing in high-functioning adults with autism. *Neuropsychologia, 45*(4), 685–695.
Jenness, J. L., Hankin, B. L., Young, J. F., & Gibb, B. E. (2014). Misclassification and identification of emotional facial expressions in depressed youth: A preliminary study. *Journal of Clinical Child and Adolescent Psychology, 44*(4), 559–565. https://doi.org/10.1080/15374416.2014.891226.
Kasari, C., Sigman, M., Mundy, P., & Yirmiya, N. (1990). Affective sharing in the context of joint attention interactions of normal, autistic, and mentally retarded children. *Journal of Autism and Developmental Disorders, 20*(1), 87–100.
Keltner, D., Moffitt, T. E., & Stouthamer-Loeber, M. (1995). Facial expressions of emotion and psychopathology in adolescent boys. *Journal of Abnormal Psychology, 104*(4), 644–652.
Korkman, M., Kirk, U., & Kemp, S. (2007). *NEPSY-II: A developmental neuropsychological assessment*. San Antonio: The Psychological Corporation.
Langdell, T. (1981). Face Perception: An approach to the study of autism. Doctoral Thesis, University of London.
Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. L. (2012). *Autism diagnostic observation schedule (ADOS-2)* (2nd ed.). Torrence: Western Psychological Services.
Loveland, K. A., Tunali-Kotoski, B., Pearson, D. A., Brelsford, K. A., Ortegon, J., & Chen, R. (1994). Imitation and expression of facial affect in autism. *Development and Psychopathology, 6*(3), 433–444.
Lozier, L. M., Vanmeter, J. W., & Marsh, A. A. (2014). Impairments in facial affect recognition associated with autism spectrum disorders: A meta-analysis. *Development and Psychopathology, 26*(4), 933–945. https://doi.org/10.1017/S0954579414000479.
Matsumoto, D., & Willingham, B. (2009). Spontaneous facial expressions of emotion of congenitally and noncongenitally blind individuals. *Journal of Personality and Social Psychology, 96*(1), 1.
Nuske, H. J., Vivanti, G., & Dissanayake, C. (2013). Are emotions impairments unique to, universal, or specific in autism spectrum disorder? A comprehensive review. *Cognition & Emotion, 27*(6), 1042–1061.
Rhind, C., Mandy, W., Treasure, J., & Tchanturia, K. (2014). An exploratory study of evoked facial affect in adolescent females with anorexia nervosa. *Psychiatry Research, 220*(1–2), 711–715. https://doi.org/10.1016/j.psychres.2014.07.057.
Ricciardi, L., Visco-Comandini, F., Erro, R., Morgante, F., Bologna, M., Fasano, A., et al. (2017). Facial emotion recognition and expression in Parkinson's disease: An emotional mirror mechanism?. *PLoS ONE, 12*(1), e0169110.
Rump, K. M., Giovannelli, J. L., Minshew, N. J., & Strauss, M. S. (2009). The development of emotion recognition in individuals with autism. *Child Development, 80*(5), 1434–1447.
Rutherford, M. D., & McIntosh, D. N. (2007). Rules versus prototype matching: Strategies of perception of emotional facial expressions in the autism spectrum. *Journal of Autism and Developmental Disorders, 37*(2), 187–196.
Sasson, N. J., Faso, D. J., Nugent, J., Lovell, S., Kennedy, D. P., & Grossman, R. B. (2017). Neurotypical peers are less willing to interact with those with autism based on thin slice judgments. *Scientific Reports, 7*, 40700.
Shalom, D. B., Mostofsky, S. H., Hazlett, R. L., Goldberg, M. C., Landa, R. J., Faran, Y., et al. (2006). Normal physiological emotions but differences in expression of conscious feelings in children with high-functioning autism. *Journal of Autism and Developmental Disorders, 36*(3), 395–400.
Stagg, S. D., Slavny, R., Hand, C., Cardoso, A., & Smith, P. (2014). Does facial expressivity count? How typically developing children respond initially to children with autism. *Autism, 18*(6), 704–711.
Tabachnick, B. G., & Fidell, L. S. (2012). *Using multivariate statistics* (6th ed.). Boston: Pearson.
Wechsler, D. (2011). *Wechsler Abbreviated Scale of Intelligence-Second Edition (WASI-II)*. San Antonio: NCS Pearson.
Yirmiya, N., Kasari, C., Sigman, M., & Mundy, P. (1989). Facial expressions of affect in autistic, mentally retarded and normal children. *Journal of Child Psychology and Psychiatry, 30*(5), 725–735.
Zonnevijlle-Bender, M. J. S., van Goozen, S. H. M., Cohen-Kettenis, P. T., van Elburg, A., & van Engeland, H. (2002). Do adolescent anorexia nervosa patients have deficits in emotional functioning? *European Child & Adolescent Psychiatry, 11*(1), 38–42. https://doi.org/10.1007/s00787-004-0351-9.