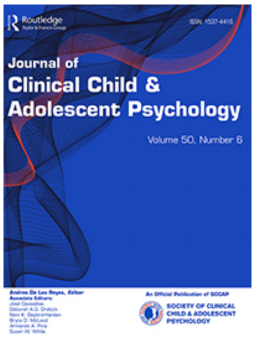

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Emotion Recognition Performance in Children with Callous Unemotional Traits is Modulated by Co-occurring Autistic Traits

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ABSTRACT

Objective: Atypical emotion recognition (ER) is characteristic of children with high callous unemotional (CU) traits. The current study aims to 1) replicate studies showing ER difficulties for static faces in relation to high CU-traits; 2) test whether ER difficulties remain when more naturalistic dynamic stimuli are used; 3) test whether ER performance for dynamic stimuli is moderated by eye-gaze direction and 4) assess the impact of co-occurring autistic traits on the association between CU and ER.

Methods: Participants were 292 (152 male) 7-year-olds from the Wirral Child Health and Development Study (WCHADS). Children completed a static and dynamic ER eye-tracking task, and accuracy, reaction time and attention to the eyes were recorded.

Results: Higher parent-reported CU-traits were significantly associated with reduced ER for static expressions, with lower accuracy for angry and happy faces. No association was found for dynamic expressions. However, parent-reported autistic traits were associated with ER difficulties for both static and dynamic expressions, and after controlling for autistic traits, the association between CU-traits and ER for static expressions became non-significant. CU-traits and looking to the eyes were not associated in either paradigm.

Conclusion: The finding that CU-traits and ER are associated for static but not naturalistic dynamic expressions may be because motion cues in the dynamic stimuli draw attention to emotion-relevant features such as eyes and mouth. Further, results suggest that ER difficulties in CU-traits may be due, in part, to co-occurring autistic traits. Future developmental studies are required to tease apart pathways toward the apparently overlapping cognitive phenotype.

Introduction

Atypicalities in socio-affective behavior are characteristic of children with high callous unemotional (CU) traits, (a proposed developmental precursor to adult psychopathy, characterized by low empathy, guilt, prosociality, sensitivity to others' emotions, and a lack of care about activities such as school work; Frick et al., 2014a). A key cognitive ability that supports adaptive socio-affective functioning is accurate emotion recognition (ER) of facial expressions. This is important for understanding other's intentions and predicting behavior, both critical components of everyday social interaction.

CU-traits are a constellation of traits that delineate a subgroup of children with conduct disorder (although these traits can appear in the absence of a diagnosis of conduct disorder) characterized by more severe and stable aggressive behavior, and increased likelihood of negative later outcomes (Burke et al., 2007; McMahon et al., 2010). Evidence suggests that conduct problems accompanied by CU-traits are more genetically influenced (Viding et al., 2005), less sensitive to punitive parenting (Dadds & Salmon, 2003) and less responsive to typical conduct problem interventions (Hawes et al., 2014). In addition to a distinct behavioral profile, CU-traits are associated with a specific set of cognitive impairments, including reduced sensitivity to punishment cues and blunted response to other's emotional responses (see Frick et al., 2014b for a review). Recently, following the psychopathy

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literature, a distinction has been made between "primary" and "secondary" CU-traits. The classic conceptualization of psychopathy and CU-traits emphasized biological or inherited risk factors in their development and a profile characterized by low or average anxiety levels. This conceptualization is now referred to as "primary" psychopathy or CU-traits, as evidence has indicated the existence of a "secondary" variant, which is thought to arise from maltreatment or traumatic experiences, and is characterized by high anxiety levels (Fanti et al., 2013; Hicks et al., 2004).

Associations between ER and CU-traits

Recognition of the emotions displayed in static pictures is impaired in individuals with CU-traits. Whilst early evidence indicated a specific impairment in the recognition of fear and sadness in individuals with CU-traits (Marsh & Blair, 2008), a recent meta-analysis indicates that the impairment is seen across both positive and negative emotions (see Dawel et al., 2012 for a review). There is some evidence to suggest ER impairments may be dependent upon the variant of CU-traits (i.e., primary vs. secondary), with one recent study of clinic-referred children finding the association between CU-traits and ER was moderated by levels of maltreatment and anxiety, although different effects were found depending on who rated maltreatment (e.g., clinician, teacher, youth) (Dadds et al., 2017).

Although the majority of ER studies use static stimuli, in the real-world facial emotional expressions are conveyed by the complex coordination of multiple facial muscle movements over time. The temporal element in dynamic expressions contains more information than a static face, and broadly improves recognition accuracy in adults (Krumhuber et al., 2013), although this may not be the case in typically developing children (Widen & Russell, 2015). Imaging studies have also demonstrated activation of social brain regions (e.g., superior temporal sulcus, amygdala) in response to dynamic but not static facial expressions (Kessler et al., 2011; Kilts et al., 2003). Mode of presentation (i.e. static versus dynamic) has recently been assessed in samples of adolescents enriched for conduct disorder and CU-traits (Martin-Key et al., 2018), with reduced recognition of fearful dynamic expressions associated with CU-traits. This study used well controlled but non-naturalistic stimuli: the image is cropped with only the central face visible and movements are created through image morphing. In the present study, one aim was to test whether reduced recognition accuracy is also associated with higher CU-traits when using more ecologically valid, naturalistic stimuli.

One commonly cited explanation for the reduced performance on ER tasks is differential patterns of attention to facial features. Compared to typically developing children, children with CU-traits show reduced attention to the eyes (Dadds et al., 2008). Atypical gaze patterns could be due to lower sensitivity to the social meaning conveyed, reduced interest, or finding the eyes aversive (Tanaka & Sung, 2016). In children with high CU-traits, ER performance improved after being explicitly cued to pay attention to the eyes (Dadds et al., 2008), suggesting the primary difficulty may be one of social motivation and/or endogenous attention control.

Gaze Direction

Another key factor that has been shown to influence the perception of emotional facial expressions is the direction of eye gaze. Adams and Kleck (2003) found that recognition of approach emotions (such as anger and happiness) is faster when there is direct eye gaze while recognition of avoidance emotions (such as fear and sadness) is facilitated by averted gaze. This paradigm used static stimuli and an adult sample, however these effects have been replicated using dynamic stimuli (Sander et al., 2007), and in child samples (Akechi et al., 2009). Adams and Kleck (2005) argued that these results can be interpreted based on the idea that the combination of gaze direction and emotional expression can be used to predict behavior. If another person's eye gaze is fearful and averted then it is important to recognize that there may be a source of danger nearby. Previously demonstrated fear recognition impairments in children with high CU-traits have primarily been tested with faces with direct gaze. In the current study, gaze direction was manipulated for the dynamic stimuli to test whether a similar interaction between ER and gaze direction is found in relation to CU-traits.

Co-occurring Autistic Traits

Atypical socio-affective behavior is also characteristic of children with autism spectrum disorder (ASD; a developmental disorder defined by social-communication difficulties with restricted and repetitive behaviors; American Psychiatric Association, 2013), and research finds high CU-traits often co-occur with ASD (Jones et al., 2010; Carter Leno et al., 2015; Rogers et al., 2006). Comparative studies have found evidence for a dissociation of cognitive profiles, in that CU-traits are typically impaired in the affective components (e.g., caring about the feelings of others) but not the cognitive components (e.g., knowing how another is feeling) of empathic response, whereas individuals with ASD show the opposite pattern (Jones et al., 2010; Rogers et al., 2006). Twin studies report that the co-occurrence of CU- and autistic traits is partially due to shared environmental influences, indicating that those environmental influences which increase the risk of CU-traits could also contribute to an increased risk for autistic traits (and vice versa) (Jones et al., 2009). Further, co-occurring autistic traits have been shown to moderate the association between CU-traits and affective empathy, with a stronger association for high versus low autistic traits (Pasalich et al., 2014).

When attempting to characterize the ER impairments associated with CU-traits, considering the role of ASD or autistic traits is pertinent, as ER, particularly for negative emotions (i.e., fear, sadness, anger), is reduced in both individuals with high levels of autistic traits (Losh et al., 2009), and those with a diagnosis of ASD (see Harms et al., 2010 for a review). Furthermore, in the aforementioned study by Akechi et al. (2009), gaze direction (direct vs. averted) did not modulate responses of children with ASD. However, it should be noted that many individual characteristics also contribute to ER ability in ASD populations (e.g., age, with strongest effects found in adult samples; Lozier et al., 2014) and impairments are often only found in certain subgroups (Loth et al., 2018) or not at all (Jones et al., 2011). A recent eye-tracking study of static ER in relation to youth with ASD diagnosis and disruptive behavior disorders (i.e. oppositional defiant disorder and conduct disorder) found both groups spent less time looking at the eyes as compared to typically developing youth (Bours et al., 2018). Differences were found in relation to ER for neutral, sad, and fearful faces (in that those with disruptive behavior disorders performed worse than those with ASD), but these did not survive adjustment for multiple comparisons.

The primary aims of the current study are to 1) to replicate the previously found association between ER and CU-traits for static expressions, 2) to test whether the same association is found in response to more ecologically valid dynamic expressions; 3) to test whether any associations between CU-traits and ER are moderated by gaze direction and 4) to test whether associations between CU-traits and ER remain when analyses are adjusted for level of autistic traits.

To test our first aim, we ran a standard ER task using static expressions from NimStim battery (Tottenham et al., 2009), to replicate previous findings. Based on extant literature we hypothesize that CU-traits will be associated with ER difficulties for static expressions and that these ER difficulties will be primarily driven by negative emotions (fear, anger, and sadness). To address our second aim, we test whether the ER difficulties associated with CU-traits are generalizable to naturalistic dynamic stimuli. For both static and dynamic stimuli, we test for negative associations between CU-traits and children's attention (measured by relative looking time to the eyes) that could underpin any associations between CU-traits and behavioral performance. To address our third aim, we first test whether there is a gaze direction-by-emotion interaction for the dynamic stimuli, if significant, we expect this to be driven by a better recognition of the approach-oriented emotions (anger and happiness) with direct gaze and the avoidance-oriented emotions (fear and sadness) with averted gaze. We then test for a CU-trait-by-gaze direction-by-emotion interaction, to test whether a similar pattern is observed in CU-traits. To address the final aim, we repeat all the outlined analyses, adjusting for the presence of autistic traits, to test the specificity of ER to CU-traits. If emotion recognition associations are specific to CU-traits then the effects should remain significant when controlling for autistic traits.

Method

Ethical approval was granted by the Cheshire North and West Research Ethics committee on 22 December 2014. Parents gave informed consent for children to participate in the study; child assent was not collected.

Participants

The Wirral Child Health and Development Study (WCHADS) is a cohort study of 1233 first time mothers and their children recruited at 20 weeks gestation (see Sharp et al., 2012). Participants were identified from consecutive first time mothers who booked for antenatal care at 12 weeks gestation between 12/02/2007 and 29/10/2008. The booking clinic was administered by the Wirral University Teaching Hospital, which was the sole provider of universal prenatal care on the Wirral Peninsula. Socioeconomic conditions on the Wirral range between the deprived inner city and affluent suburbs, but with low numbers from ethnic minorities (upon study entry 96.1% of the mothers were White British). The study was introduced to the women by clinic midwives who asked for their agreement to be approached by study research midwives when they attended for ultrasound scanning at 20 weeks gestation. The only exclusion criteria for mothers were: age younger than 18 years at 20-week scan and non-English speaking. Any children with gross congenital abnormalities (and their mothers) were subsequently excluded from the study after birth.

An intensively studied (hereby intensive) subsample of 316 participants, stratified based on partner psychological abuse at 32 week gestation, and supplemented at 3.5 years by an additional stratum including 75 children who scored above cut off on the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2000) internalizing or externalizing scales and/or Antisocial Process Screening Device (APSD; Frick & Hare, 2001, see Wright et al., 2019 for details). In the current study, data were analyzed from 292 (153 males) 7-year-old children (mean age/years = 7.25, SD = .225) from the intensive subsample.

Parent-reported Questionnaires

The Social Communication Questionnaire (SCQ; Rutter, Bailey et al., 2003) was used to measure autistic traits. The SCQ is a 40-item questionnaire based on "gold-standard" ASD diagnostic instruments (Rutter, Couteur et al., 2003). Statements are scored 0–1, according to whether certain behaviors have been observed in the last 3 months (yes/no), with a higher total score overall indicating a higher level of autistic traits. Good internal consistency and validity is reported (Berument et al., 1999).

The Inventory of Callous-Unemotional Traits (ICU; Frick, 2004) was used to measure CU-traits. The ICU includes 24 items that tap multiple aspects of the affective features of CU-traits, scored 0–3 (not at all true, somewhat true, very true, definitely true). Higher scores on the ICU are associated with higher levels of conduct problems and psychosocial impairment (Essau et al., 2006), and the measure is found to have good internal consistency (Essau et al., 2006; Viding et al., 2009).

Apparatus

Participants were seated at a distance of approximately 45 cm from the 17-inch-flat touchscreen monitor (1600 x 900 resolution) and looking behavior was recorded using a Tobii X2-60 eye-tracker. Stimuli were presented using Tobii Studio and gaze data were recorded at 60 Hz.

Stimuli and Procedure

Static ER Paradigm

Before beginning the experimental tasks, a five-point calibration sequence was run. Each trial consisted of a centrally presented fixation cross (screen location 800 × 450) on a black background (1 second), followed by a static picture of an actor portraying a specific emotion (2 seconds; positioned at screen center), and then a choice screen displaying five words (happy, sad, angry, scared, neutral) (see Figure 1). The central fixation cross, which appeared before the face, was in the location of the nose bridge on the face stimuli. Participants chose the word that matched the emotion they had seen portrayed in the preceding picture and the experimenter used the mouse to select this response. The choice screen was displayed until a response was detected. Each of the five emotions (happiness, sadness, anger, fear, and neutral) was presented four times, giving 20 trials in total. Stimuli were selected from the NimStim Face-Stimulus database (Tottenham et al., 2009), using equal numbers of male and female actors. There were three White male and three White female faces. Two female and two male faces were repeated 3 times each (always showing a different emotion), and one female and one male face were repeated 4 times (again always showing different emotion), to give a total of 20 trials. Face stimuli subtended 8.83° horizontally by 11.09° vertically. The order of trial presentation was counterbalanced across participants.

Dynamic ER Paradigm

To create the dynamic stimuli, adult White female volunteers were positioned 70 inches away from the camera and filmed performing different emotional expressions. Raw video footage was edited in Windows Movie Maker and exported as .wmv format (resolution: 1280*720; frame rate: 29.97). Each trial consisted of a centrally presented fixation cross on a scrambled background (2.5 seconds), followed by a centrally positioned dynamic video of one of four female actors portraying a specific emotion (1.5 seconds of motion, followed by 1 second freeze-frame static image of the expression), another centrally presented fixation cross on a scrambled background (1 second), and then a choice screen displaying four static pictures of different actors portraying different emotions (8 seconds) (see Figure 2). Because the faces were three quarter view, the centrally presented fixation cross (which appeared before the face) varied slightly in terms of its location on the face, depending on the model, between the central nose bridge and the left eye. As part of initial piloting in 10 adults and 12 children, the 1 second freeze-frame of a static face was included to make sure participants had enough time to view the face before responding, in order to avoid floor effects. The scrambled background was a luminance-matched shuffled pixel version of the face used to eradicate afterimages. Participants were instructed to select the picture of the emotion that matched the emotion they had seen portrayed in the preceding video. Again, five emotions (happiness, sadness, anger, fear, and neutral) were presented four times, giving 20 trials in total. For each emotion, two trials

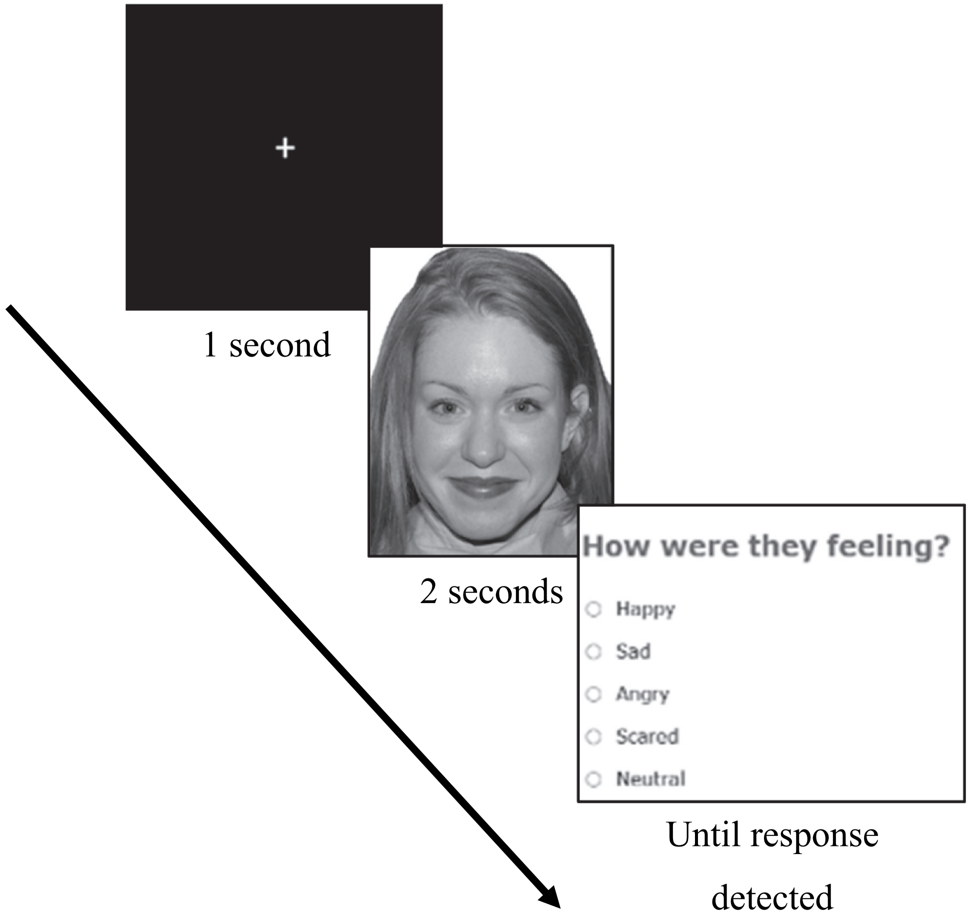

Figure 1. Diagram of experimental design for static ER paradigm.

displayed averted gaze in the dynamic video (gaze moves from head central to averted) and two displayed direct gaze (gaze moves from head central to direct). In the two gaze conditions, the correct response was counterbalanced in terms of congruence of gaze between the dynamic video and the static faces (e.g., 50% of the time the correct responses was a face with averted gaze and 50% of the time it was a face with direct gaze). The order of trial presentation was randomized. The target face stimuli subtended 20.62° horizontally by 15.28° vertically.

Children completed up to six practice trials before beginning both the Static and Dynamic ER paradigms. They were allowed to practice until it was clear that they understood the task.

Data Analysis

Behavioral Data

Accuracy and RT were collected from the dynamic paradigm, and accuracy only from the static paradigm as RT was not available. RT for the dynamic trials was calculated only for those trials in which the response was correct. Trials were excluded if no gaze samples were collected during initial stimulus presentation (i.e. the participant had not been paying attention to the stimulus before making a response). One participant had no gaze data for any trials in either the static or dynamic paradigms. Although visual inspection of the recording indicated this was simply because the eye-tracker did not detect their eyes, they were never-the-less excluded based on the above criteria (giving a final sample size N = 291). Following these exclusions, for the static paradigm participants had an average of 97.4% valid trials. Additionally, in the dynamic paradigm, trials were excluded if no response was made during the choice screen after successful viewing of the dynamic video (as indicated by valid gaze data being collected during stimulus presentation). This criterion was not applicable to the static paradigm as the experiment would not move on to the next trial until a response was detected. Following these exclusions, participants had an average of 82.8% valid trials for the dynamic task.

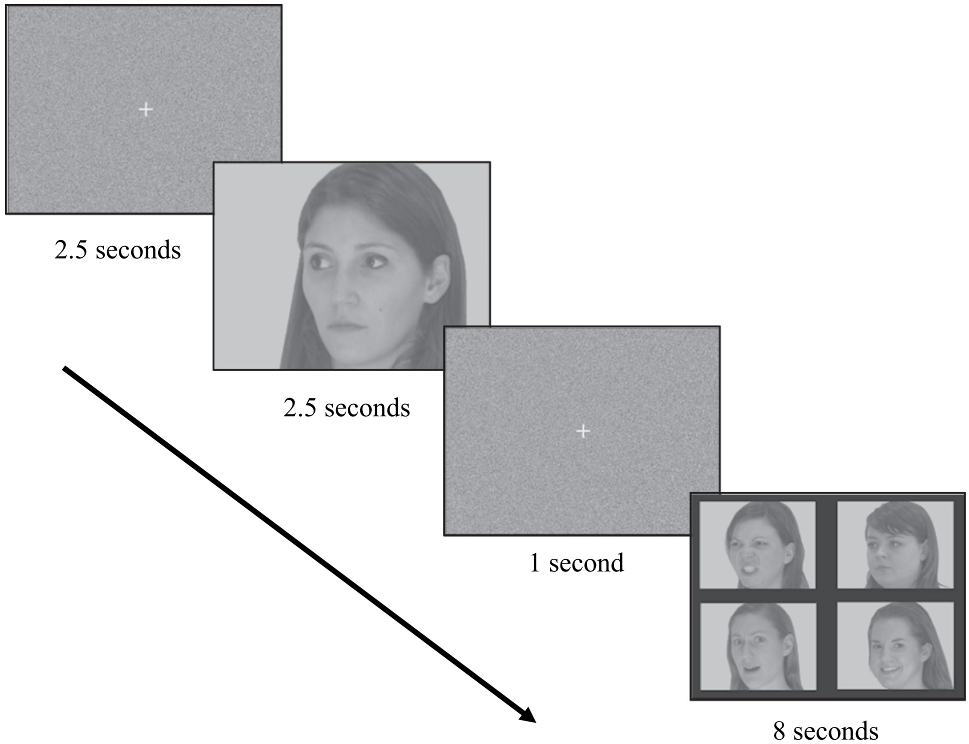

Figure 2. Diagram of experimental design for dynamic ER paradigm.

Gaze Data

Within each trial, a rectangular area of interest (AOI) was defined around the eye region using Tobii Studio. In both static and dynamic paradigms, static AOIs were drawn to include the eye region allowing a minimum margin of 1 cm (0.63°). Total looking time was extracted for this AOI, along with that for the whole screen during stimulus presentation. Trials were excluded if less than 50% of gaze samples were collected during stimulus presentation (i.e. during the 2.5 second presentation of face). Participants who had less than 50% of valid trials were excluded from gaze analyses (n = 8, 2.7% for the static and n = 36, 12.3% for dynamic paradigm, respectively). These moderately stringent criteria were used to ensure the gaze data were reliable.

Looking Time During Stimulus Presentation

Looking time to the eyes was calculated as the total duration of looking to the defined eye AOI/total looking time at the screen.

Statistical Analysis

Generalized estimating equation (GEE) analyses were run in SPSS (IBM Corp., 2017). GEEs were chosen to account for correlations between responses for different emotions, as well as to deal with missing data. For the static ER tasks, accuracy was analyzed using an ordinal model with a logit link function and an exchangeable working correlation matrix with robust standard errors. An accuracy proportion over the trials for each emotion was calculated, giving an ordinal variable with scores between 0 and 1. Looking time to the eyes *versus* the rest of the screen was analyzed using a Gaussian model with identity link function and unstructured correlation matrix. RTs and looking time were analyzed using a Gaussian model with an identity link function and unstructured correlation matrix. In primary analyses assessing the association between CU-traits and ER, covariates included child's age, sex, and socioeconomic deprivation (participants were ranked according to their area postal code and assigned to a quintile based on the United Kingdom distribution of deprivation; Noble et al., 2004). Main effects models were run first, and then interactions were added. Finally, autistic traits were then included as an additional covariate across analyses to determine specificity of effects to CU-traits. Unstandardized coefficient values are presented for the main effect of CU-traits to aid with interpretation of directionality. Unstandardized estimates are the default from SPSS and represent unstandardized beta coefficients in linear GEE and log odds in ordinal logistic GEE models.

Models testing associations between ER and autistic traits only (without CU-traits) are reported in the Supplementary Materials. Although the association between autistic traits and ER is not the focus of the current paper, the models test whether there was a main effect of autistic traits before accounting for CU-traits in the models, thus aiding interpretation of any change in associations with CU-traits once autistic traits are included. Distributional plots were created in Python (version 3.7).

Results

Descriptive statistics for emotions are presented in Tables 1 and 2, Figure 3a and 3b depict the distribution of key variables from the Static and Dynamic paradigms, respectively. Mean CU-trait scores, as measured by ICU (N = 277), were 17.08 (SD = 7.80). Mean autistic traits, as measured by the SCQ (N = 268), were 0.13 (SD = 0.12). Autistic and CU-traits were significantly positively correlated, r = 0.396, p < .001.

Static Emotion Recognition Task

Static Accuracy

Overall mean accuracy across emotions was 0.76 (SD = 0.14). An ordinal logistic GEE (see Table 3) showed a significant main effect of Emotion (p < .001, see Table 1). The main effect of CU-traits did not reach significance (B = −.014, p = .092) but there was a marginally significant interaction between Emotion and CU-traits (p = .050). Age, deprivation index, and sex were not significant predictors of accuracy. As we had hypothesized that we would find differential associations between CU-traits and task performance across emotions, we followed up this marginal effect with posthoc analyses. Re-running the same GEE model separately for each emotion showed that higher CU-traits were significantly associated with reduced recognition for angry (Wald $\chi^2(1)$ = 6.059, B = −.037, p = .014) and happy (Wald $\chi^2(1)$ = 7.745, B = −.064, p = .005) faces, but no significant association for other emotions (all p values > .35).

When controlling for autistic traits, the marginal interaction between CU-traits and emotion became non-significant (p = .151, see Table 3). There was a significant main effect of autistic traits with higher traits associated with poorer overall ER performance (p = .003).

Static Relative Looking to the Eyes

Mean relative looking time to the eyes across emotions was 0.49 (SD = 0.18). Increased looking time to the eyes was significantly correlated with recognition accuracy (r = 0.277, p < .001). A linear GEE showed a significant main effect of Emotion (p < .001), see Table 1). There was no main effect of CU-traits (B = −.001, p = .482), nor an Emotion*CU-trait interaction (p = .193), and covariates age, deprivation index and sex were not significant. Adding a main effect of autistic traits did not change model results, and there was no main effect of autistic traits.

Dynamic Emotion Recognition Task

Dynamic Accuracy

Overall mean accuracy across emotions was 0.86 (SD = 0.14). An ordinal logistic GEE (see Table 4) showed a significant main effect of Emotion (p < .001, see Table 2) and gaze direction (p = .010; mean accuracy: direct = 0.87, averted = 0.84). There was no significant main effect of CU-traits (B = .005, p = .550). Covariates age and deprivation did not reach significance, but there was a main effect of sex (p = .007), with greater ER accuracy in females (mean accuracy: males 0.84, females 0.88). The two- and three-way interaction with CU-traits were not significant, but there was a significant Emotion*Gaze interaction (p = .008). Running separate GEE models for each emotion, showed that there was a significant main effect of gaze direction only for sad expressions (Wald $\chi^2(1)$ = 10.299, p = .001) with greater accuracy for faces with direct (mean = 0.93) compared to averted (mean = 0.85) gaze.

Results remained substantively similar when including autistic traits in the model, and there was a significant

Table 1. Descriptive statistics for static emotion recognition task.

Emotion	Accuracy Mean (SD)	Relative Attention to Eyes Mean (SD)
Angry	.579 (.264)	.514 (.191)
Happy	.945 (.135)	.459 (.213)
Sad	.806 (.232)	.512 (.191)
Scared	.712 (.293)	.500 (.200)
Neutral	.755 (.216)	.468 (.202)

Table 2. Descriptive statistics for dynamic emotion recognition task.

Emotion	Accuracy Mean (SD)	Reaction Time Mean (SD)	Relative Attention to Eyes Mean (SD)
Angry	.871 (.229)	3.455 (.903)	.569 (.206)
Happy	.907 (.178)	3.388 (.870)	.544 (.206)
Sad	.890 (.209)	3.510 (.806)	.636 (.188)
Scared	.728 (.309)	4.247 (.990)	.623 (.191)
Neutral	.881 (.197)	3.628 (.884)	.662 (.197)

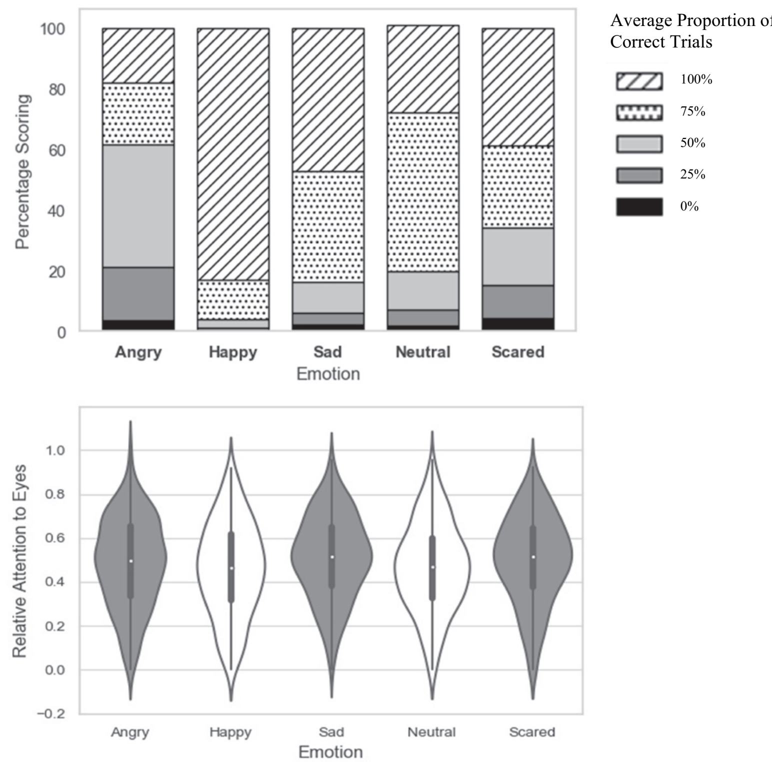

Figure 3. (a) Accuracy and relative looking time to the eyes across emotions in the static emotion recognition paradigm. The low numbers of participants scoring 33% or 66% (due to missing data) have been collapsed into 25% and 75% categories respectively to aid interpretability. The white dot represents the median, the thick gray bar represents the interquartile range, the thin gray line represents the rest of the distribution of scores (excluding outliers). Wider sections of the violin plots represent a higher probability that members of the population will take on the given value.

main effect of autistic traits (p = .027), with higher traits associated with reduced ER performance.

Dynamic RT

Mean RT across emotions was 3.63 seconds (SD = 0.626). Faster RTs were not significantly correlated with increased accuracy (r = −0.096, p = .101). A linear GEE model showed a significant main effect of Emotion (p < .001, see Table 2), but no main effect of gaze direction (p = .764), CU-traits (B = −.007, p = .164), or covariates age, sex and deprivation index. The two- and three-way interactions with CU-traits were not significant, but there was a significant Emotion*Gaze interaction (p = .031). Re-running the GEE model separately for each emotion showed that there was a significant main effect of gaze direction only for happy expressions, Wald $\chi^2(1)$ = 4.875, p = .027. RTs were faster for faces with direct (mean = 3.27 seconds) compared to averted (mean = 3.50 seconds) gaze. When controlling for autistic traits, results remained substantively similar and there was no main effect of autistic traits (p = .708). The effect of CU-traits became marginal, in the direction that higher CU-traits were associated with slightly *faster* RTs (B = −.007, p = .070).

Dynamic Relative Looking to the Eyes

Mean relative looking time to the eyes across emotions was 0.61 (SD = 0.171). Increased looking time to the eyes was not significantly correlated with accuracy (r = 0.092, p = .145) or RT (r = 0.043, p = .498). A linear GEE showed a significant main effect of Emotion (p < .001), see Table 2). Gaze direction was marginally significant (p = .077), with slightly increased looking to the eyes for faces with direct gaze (mean proportion of attention to eyes: direct = 0.62, averted = 0.59. There was no main effect of CU-traits (B < .001, p = .773). Covariates age and sex were not significant. There was a significant effect for deprivation (p = .002) with significantly less looking to the eyes in the least deprived group compared to all others (p values ≥ .006; means for each quintile from most deprived to least deprived: 1 = 0.60, 2 = 0.58, 3 = 0.52, 4 = 0.61, 5 = 0.40). There were no significant interactions. Adding autistic traits did not substantively change any of the results, nor was there a main effect of autistic traits.

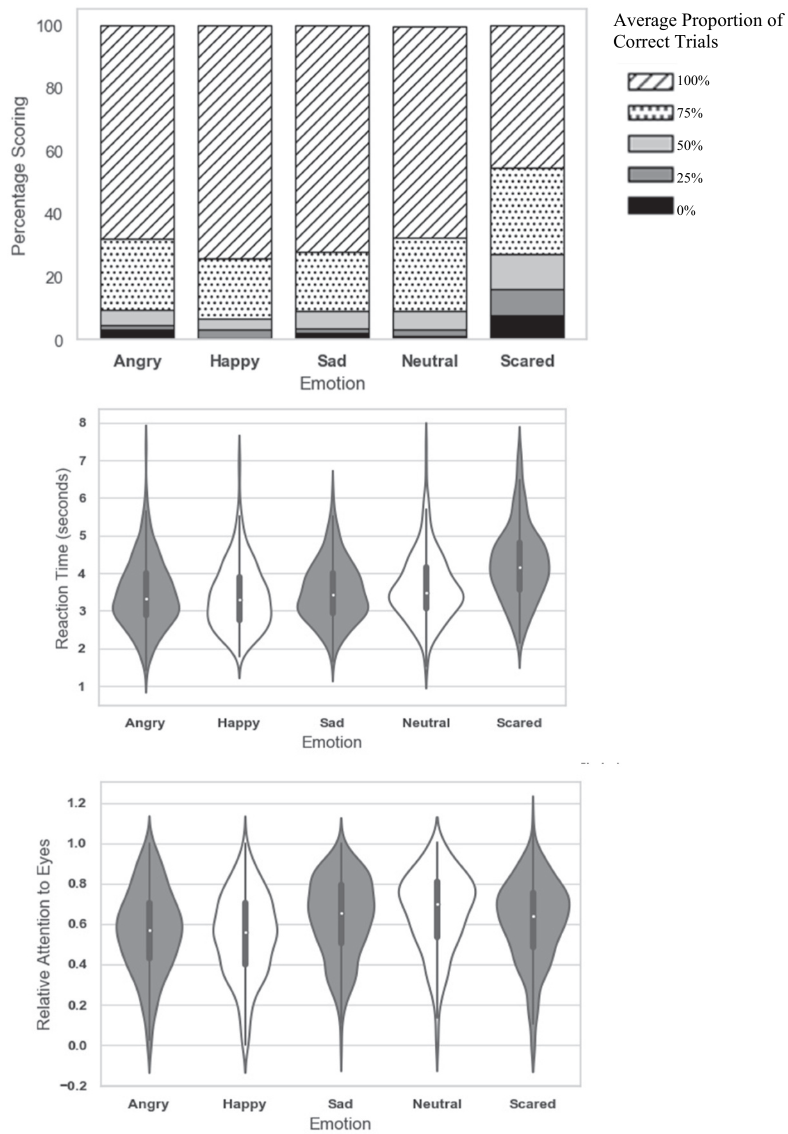

Figure 3. (b) Accuracy, reaction times and relative looking to the eyes across emotions in the dynamic emotion recognition paradigm. The low numbers of participants scoring 33% or 66% (due to missing data) have been collapsed into 25% and 75% categories respectively to aid interpretability. The white dot represents the median, the thick gray bar represents the interquartile range, the thin gray line represents the rest of the distribution of scores (excluding outliers). Wider sections of the violin plots represent a higher probability that members of the population will take on the given value.

Discussion

Our results showed a significant association between CU-traits and ER for static facial expressions, with higher CU-traits associated with reduced accuracy for angry and happy faces. For dynamic faces, no significant association with CU-traits was found. No associations were found between relative looking time to the eyes and CU-traits for either task. Reduced ER accuracy was associated with higher autistic traits for both static and dynamic facial expressions. When controlling for autistic traits, the association between CU-traits and static ER became non-significant, suggesting that co-occurring autistic traits may have contributed toward the observed association between CU-traits and ER.

Emotion Expression Influences Recognition

For static ER we found a significant main effect of emotion for both recognition accuracy and looking time to the eyes. Accuracy was highest for happy faces (0.95) and lowest for angry faces (0.58). CU-traits were specifically associated with lower accuracy for angry and happy faces. Traditionally CU-traits were thought to be associated with a specific impairment in recognizing negative

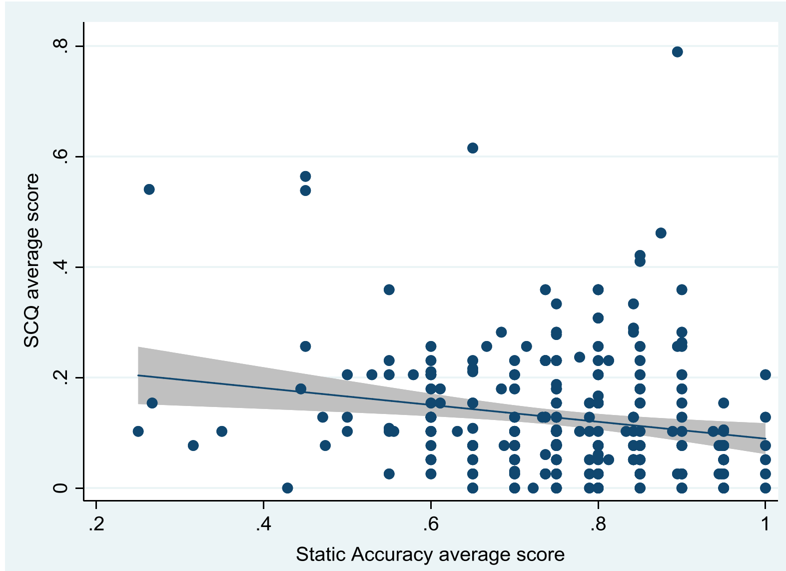

Figure 4. Scatterplot of autistic traits measured by social communication questionnaire (SCQ) and static emotion recognition average score.

emotions (Marsh & Blair, 2008), however, our findings are more consistent with the recent meta-analysis indicating associations with impaired recognition of both positive and negative emotions (Dawel et al., 2012), although we did not observe impairment for scared and sad faces. In a recent study of a clinic-referred sample, Dadds et al. (2018) found significant interactions between maltreatment and ER impairment across all emotions, including for fearful and sad faces, such that there was no association between CU-traits and ER in the high maltreatment group. It may be that fear and sadness specific effects are somewhat masked in the current sample by the likely mix of both "primary" with more "secondary" type CU-traits, the latter being associated with early exposure to maltreatment (Kimonis et al., 2012). Studies of physiological reactivity have found reduced reactivity to fearful stimuli in primary compared to secondary groups of children (Fanti et al., 2018) and adolescents (Kimonis et al., 2016). However, Fanti et al. also tested reactivity to sad stimuli and found no difference between the two groups. Future research is needed examining emotion processing in samples of children belonging to primary and secondary CU-traits groups.

For looking time, as expected, attention to the eyes differed by emotion, with least looking in happy faces (0.46), where the mouth rather than the eyes is the key feature in ER, and highest attention to the eyes for angry (0.51), sad (0.51) and scared (0.50) faces. A similar main effect of emotion was found in the dynamic paradigm. Performance was best for happy faces (accuracy: 0.91, RT: 3.39s) and worst for scared expressions (accuracy: 0.73, RT: 4.21s). Looking to the eyes was lowest for happy faces (0.55) and highest for sad (0.64) and neutral faces (0.66). The results from both static and dynamic tasks are consistent with previous literature which shows recognition performance in children is strongly influenced by emotional expression, with most accurate performance for happy expressions (e.g., Camras & Allison, 1985; Herba et al., 2006).

Static and dynamic emotion recognition in CU-traits

While accuracy was associated with emotion expression in a similar way across the static and dynamic tasks, only accuracy in the static task, not the dynamic task, was associated with CU-traits. Why might associations between performance and CU-traits differ between the tasks? First, recognition may be easier for dynamic stimuli where the temporal dimension increases the available information compared to a static facial expression (Krumhuber et al., 2013). Although the current study was not designed to directly test performance between the two paradigms, as they use both different stimuli and mode of response (labeling in the static paradigm versus matching to emotional expressions in the dynamic paradigm), at the descriptive level we see higher overall accuracy in the dynamic (0.86) as compared to static (0.76) paradigm. It is also possible that the dynamic stimuli are more interesting and engaging. This is supported by greater overall relative looking time to the eyes in the dynamic (0.61) compared to static (0.49) paradigm. Dadds et al. (2008) found that when children with high CU-traits were specifically cued to the eyes of fearful faces, recognition accuracy improved. It may be that with static stimuli children with high CU-traits are

Table 3. Static emotion recognition results.

		CU model Wald χ^2 (df), *p* value	ASD as a covariate Wald χ^2 (df), *p* value
Accuracy	Emotion	**333.365 (4), *p* < .001**	**319.249 (4), *p* < .001**
	CU-traits	2.838 (1), *p* = .092	.043 (1) *p* = .836
	Sex	.515 (1), *p* = .473	.033 (1) *p* = .857
	Age	.425 (1), *p* = .515	.102 (1), *p* = .750
	Deprivation quintile	7.027 (4), *p* = .134	7.479 (4) *p* = .113
	Autistic Traits	-	**8.584 (1) *p* = .003**
	Emotion*CU-traits	**9.501 (4), *p* = .050**	6.730 (4) *p* = .151
Relative Attention to Eyes	Emotion	**64.066 (4), *p* < .001**	**59.067 (4), *p* < .001**
	CU-traits	.495 (1), *p* = .482	.053 (1) *p* = .817
	Sex	.128 (1), *p* = .721	.130 (1) *p* = .719
	Age	.468 (1), *p* = .494	.381 (1), *p* = .537
	Deprivation quintile	5.960 (4), *p* = .202	8.099 (4) *p* = .088
	Autistic Traits	-	2.746 (1) *p* = .097
	Emotion*CU-traits	6.080 (4), *p* = .193	8.194 (4) *p* = .085

Table 4. Dynamic emotion recognition results.

		CU model Wald χ^2 (df), *p* value	ASD as a covariate Wald χ^2 (df), *p* value
Accuracy	Emotion	**111.525 (4), *p* < .001**	**95.597 (4), *p* < .001**
	Gaze	**6.628 (1), *p* = .010**	**5.320 (1), *p* = .021**
	CU-traits	.357 (1), *p* = .550	2.675 (1) *p* = .102
	Sex	**7.376 (1), *p* = .007**	3.324 (1) *p* = .068
	Age	.143 (1), *p* = .705	0.030 (1), *p* = .863
	Deprivation quintile	3.906 (4), *p* = .419	5.49 (4) *p* = .241
	Autistic Traits	-	**4.862 (1) *p* = .027**
	Emotion*CU-traits	3.789 (4), *p* = .435	2.553 (4) *p* = .635
	Gaze*CU-traits	.156 (1), *p* = .693	.322 (1), *p* = .570
	Emotion*Gaze	**13.912 (4), *p* = .008**	**14.974 (4), *p* = .005**
	Emotion*Gaze*CU-traits	6.14 (4), *p* = .189	7.405 (4), *p* = .116
Reaction Time	Emotion	**233.521 (4), *p* < .001**	**217.821 (4), *p* < .001**
	Gaze	.090 (1), *p* = .764	.153 (1), *p* = .696
	CU-traits	1.939 (1), *p* = .164	3.278 (1) *p* = .070
	Sex	2.844 (1), *p* = .092	2.157 (1) *p* = .142
	Age	.001 (1), *p* = .982	.117 (1), *p* = .732
	Deprivation quintile	2.438 (4), *p* = .656	2.236 (4) *p* = .692
	Autistic Traits	-	.140 (1) *p* = .708
	Emotion*CU-traits	.995 (4), *p* = .911	1.309 (4) *p* = .860
	Gaze*CU-traits	.167 (1), *p* = .683	.557 (1), *p* = .455
	Emotion*Gaze	**10.663 (4), *p* = .031**	**10.282 (4), *p* = .036**
	Emotion*Gaze*CU-traits	2.981 (4), *p* = .561	2.690 (4), *p* = .611
Relative Attention to Eyes	Emotion	**161.845 (4), *p* < .001**	**140.877 (4), *p* < .001**
	Gaze	3.130 (1), *p* = .077	**3.851 (1), *p* = .050**
	CU-traits	.083 (1), *p* = .773	.720 (1), *p* = .396
	Sex	.001 (1), *p* = .976	.323 (1), *p* = .570
	Age	.040 (1), *p* = .841	.012 (1), *p* = .912
	Deprivation quintile	**17.170 (4), *p* = .002**	**18.773 (4), *p* = .001**
	Autistic Traits	-	2.351 (1), *p* = .125
	Emotion*CU-traits	6.690 (4), *p* = .153	5.457 (4), *p* = .244
	Gaze*CU-traits	1.167 (1), *p* = .280	1.160 (1), *p* = .281
	Emotion*Gaze	5.103 (4), *p* = .277	3.838 (4), *p* = .428
	Emotion*Gaze*CU-traits	3.887 (4), *p* = .421	3.033 (4), *p* = .552

simply less interested (and therefore less likely to give an accurate response), but when motion captures attention and cues looking to the eyes, performance normalizes. This is consistent with the idea that the drive for social affiliation is reduced in children with high CU-traits (Viding & McCrory, 2019). Future studies should exploit real-world eye-tracking techniques to test whether attention to emotional cues in ecologically valid settings such as parent–child interactions (e.g., as in Yu & Smith, 2016) is associated with CU-traits.

The fact that we do not find any association between CU-traits and ER in the dynamic paradigm is not consistent with a recent paper which used well-controlled morphed dynamic stimuli (Martin-Key et al., 2018) and found an association between fear recognition and CU-traits in adolescents (aged 13–18 years). As well as differences in the age of participants, there are several key differences between the stimuli that could explain the discrepant findings. One possibility is that stimuli used in the current task may provide more information than those used previously. The length of presentation was much shorter in Martin-Key et al. (2018); 1 s versus the 2.5 s in the current study. This 2.5 s included 1.5 s of change followed by 1 second of the static expression at the end, and likely offered increased information about the expression. Furthermore, Martin-Key et al. (2018) used tightly controlled morphed stimuli whereas the current stimuli are naturalistic, more similar to emotional expressions encountered in everyday life. The dynamic stimuli in the current study show the whole head including the hairline and provide detailed 3D information through three quarter face pose, which increases the information available about the musculature driving facial expressions and may improve recognition ability (see Hu et al., 2008). Additionally, compared to the morphed, grayscale stimuli used by Martin-Key et al. (2018) the current stimuli are more complex images which include redundancy in color, depth, and facial dynamics, all of which may aid recognition accuracy. Alternatively, as suggested above, the dynamic, colored stimuli may be more engaging, and the impairments found by Martin-Key et al. (2018) may be due to reduced attention, in a similar manner to that observed for static stimuli (Dadds et al., 2008). Future work is needed to isolate and test these different components of ER to determine the precise nature of impairments in relation to CU-traits.

For the dynamic task only, gaze direction was manipulated. There was a main effect of gaze for accuracy, with better recognition of emotions in faces with direct gaze. The significant gaze-by-emotion interaction for accuracy showed this was driven by better recognition of direct versus averted gaze for sad facial expressions, and for RT the significant interaction was driven by faster recognition for happy direct compared to averted gaze. In terms of looking time to the eyes, gaze was marginally significant with slightly more looking to the eyes for direct versus averted gaze. The main effect of gaze on accuracy is consistent with previous literature showing that perceived eye gaze direction influences subsequent social cognitive processing (see Senju & Johnson, 2009 for a review). For example, direct gaze is associated with increased encoding and memory for facial identity (Hood et al., 2003) and faster gender categorization (Macrae et al., 2002). Our finding of increased looking to the eyes during direct gaze is also consistent with findings by Senju and Hasegawa (2005) that direct gaze captures attention. However, we did not show the expected effects of gaze direction moderating recognition. Superior recognition of approach-oriented emotions (anger, happiness) with direct gaze and avoidance-oriented expressions (fear, sadness) with averted gaze has been shown previously for both static (Adams & Kleck, 2005, 2003) and dynamic faces (Sander et al., 2007). Somewhat in line with this, we found faster RTs for happy although not angry expressions when gaze was direct, and no difference in accuracy. However, we found no evidence to support enhanced recognition of fearful and sad facial expressions when gaze was averted; indeed results showed significantly increased accuracy for direct versus averted sad facial expressions, and no differences for either expression in RT. One possible explanation for the discrepancy in findings is the fact we presented a three quarter view of the faces. Kliegl et al. (2015) found that head direction influenced the perception of emotional expression. Participants were more likely to categorize a face as angry versus neutral, when the head was facing the participant, and likelihood reduced with degree of aversion. Further, they observed a similar pattern of effects across emotions, and although they did not test fearful faces, they argue that an averted head direction, i.e., "turning away" indicates a lack of social interest irrespective of emotion expression. Thus, our partially averted head direction may have reduced the influence of gaze direction on recognition accuracy.

No association between relative looking time to the eyes and CU-traits was found for either task. For the dynamic paradigm, this may have been due to the increased engagement due to the naturalistic stimuli used and/or the motion in the gaze shift. However, an alternative explanation is that in both paradigms the position of the fixation cross cued the participants to look toward the eye area before the facial stimuli were displayed, as both the cross and the eyes were located in the central area of the screen. The choice of a central fixation location has advantages – namely, it is a more relaxed viewing position for the eyes, it controls for differences in disengaging and shifting attention from an offset location, something known to be atypical in autism (Landry & Bryson, 2004) and central fixation and stimulus presentation is commonly used in ER tasks (e.g., Akechi et al., 2009). However, this fixation location may have increased early overt or covert attention to the eye region, thus explaining the lack of significant association between CU-traits and looking time to the eyes. Given that previous work has found that individuals with CU-traits can be cued to look at the eyes, and that cueing normalized task performance (Dadds et al., 2008), incidental cueing effects may in part explain the lack of association between CU-traits and looking to the eyes. However, a cuing effect of the fixation cross cannot readily explain the pattern of results for accuracy, given that emotion recognition accuracy *was* associated with CU-traits in the static paradigm but not in the dynamic paradigm.

Emotion Recognition and CU-traits: Controlling for Autistic Traits

For both the static and dynamic paradigms, we found a significant effect of autistic traits on ER accuracy, with higher traits associated with reduced ER accuracy. However, there was no significant association between RT and autistic traits in the dynamic paradigm (RT was not collected in the static paradigm). We found a marginal association between autistic traits and looking time to the eyes for static expressions (similar to Bours et al., 2018), in the direction of reduced looking to the eyes overall, but no effect for dynamic expressions. We included autistic traits in the model to test whether they modulated the association between CU-traits and ER. For static expressions, the marginal interaction between CU-traits and emotion in predicting ER accuracy became non-significant when covarying for autistic traits. Further, for dynamic expressions, when accounting for autistic traits the association between RT and CU-traits became marginally significant with *faster* RTs associated with higher CU-traits. As this latter result was not predicted a priori, we do not interpret it further. The drop in significance of the marginal interaction between CU-traits and emotion in predicting accuracy could be because the ER difficulties typically thought of as characteristic of CU-traits are actually due, at least in part, to co-occurring autistic traits. However, it is also possible that drop in significance in part reflect difficulties with discriminating superficially overlapping aspects of CU-traits and autistic traits with a high enough degree of specificity when using parent-report measures. For example, Carter Leno et al. (2015) note that symptoms such as sensitivity to the feelings of others, may be driven by very different mechanisms in relation to autistic and CU-traits, but may appear superficially similar at the behavioral level. This is supported by empirical work that has found that measures of autistic traits (the Social Responsiveness Scale; SRS) are also predicted by level of CU-traits (Moul et al., 2015). The same could be true of the measure of autistic traits used in the current study (the Social Communication Questionnaire; SCQ), and thus where analyses adjust for autistic traits this could also remove some of the true effects of CU-traits. However, we note literature suggesting the SCQ has higher specificity than the SRS (Charman et al., 2007; Moody et al., 2017), even in children with autism and high levels of aggressive or conduct-disordered behavior (likely correlated with CU-traits). Future psychometric studies will be helpful to establish whether particular questionnaire items are better at discriminating CU-traits from ASD (similar to that in Moul et al., 2015). Future experimental studies are also needed to test whether the mechanisms underlying ER difficulties are similar in ASD and CU-traits – it may be that differential factors, such as atypical domain-general attention control and/or domain-specific social motivation are responsible for similar patterns of ER behavior at the phenotypic level.

What is clear, given the changes in associations between CU-traits and task performance once autistic traits were included in the model, is the importance of considering overlapping traits, rather than looking at effects of disorder-traits in isolation (Dadds & Frick, 2019). Future work should also consider the potential role of co-occurring alexithymia, which is characterized by difficulties in recognizing and interpreting emotions both in oneself and others (Bird & Viding, 2014). In line with a recent transdiagnostic shift (e.g., RDoC; Insel et al., 2010), our findings also emphasize the importance of moving beyond impairments in cognitive functioning associated with diagnostic categories to looking at the domains of cognitive functioning themselves (e.g., ER) and how the profile of strengths and difficulties across a variety of domains may explain variation in which symptoms an individual may exhibit.

The current study uses a large, well-characterized sample, and benefits from the inclusion of both a static and dynamic task using eye-tracking along with psychometrically validated measures of CU-traits (Frick, 2004) and autistic traits (Berument et al., 1999; Rutter, Bailey et al., 2003). However, there are several key limitations that should be discussed. First, while measured on the same children, the static and dynamic paradigms used very different stimuli and required different types of responses to measure performance (e.g., matching vs. labeling). It would be ideal to use static stills taken from the dynamic clips and the same response method to allow a better-controlled comparison of ER for static versus dynamic expressions. That said, the static stimuli are well validated, and have been widely used to measure ER impairments in youth with CU-traits across a variety of samples (Bours et al., 2018; Sebastian et al., 2013; White et al., 2016), thus providing a reliable baseline of the children's abilities. The use of naturalistic stimuli has both advantages and disadvantages. While they can offer a closer approximation to ER in the real world, the reduced control can hinder inference regarding the underlying mechanisms that influence performance.

We also acknowledge that the current sample is ethnically homogeneous, and therefore further replication is required in more diverse samples.

In conclusion, the current study shows an association between CU-traits and ER for static but not dynamic faces. This is consistent with the hypothesis that atypical social attention is driving the ER differences in CU-traits, rather than global difficulties in social cognition. Further, we suggest that certain ER difficulties associated with CU-traits may be due, in part, to co-occurring autistic traits. In order to more fully understand the mechanisms underlying ER difficulties associated with autistic and CU-traits, future developmental studies are required to tease apart the pathways toward a partially shared cognitive phenotype.

Research Highlights

- Callous unemotional (CU) traits are associated with reduced emotion recognition for static faces but not for naturalistic dynamic stimuli.
- The association between CU-traits and static emotion recognition becomes non-significant after controlling for autistic traits.
- Results emphasize the importance of considering co-occurring traits, and the potential importance of moving beyond diagnostic categories to considering domains of cognitive functioning.

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