Received: 6 February 2023 | Accepted: 6 July 2023

DOI: 10.1002/aur.2993

RESEARCH ARTICLE

# Empathy deficits, callous-unemotional traits and structural underpinnings in autism spectrum disorder and conduct disorder youth

**Antonia Tkalcec**[1] | **Maria Bierlein**[1] | **Gudrun Seeger-Schneider**[2] | **Susanne Walitza**[2] | **Bettina Jenny**[2] | **Willeke M. Menks**[3,4] | **Lynn V. Felhbaum**[5] | **Reka Borbas**[5] | **David M. Cole**[6] | **Nora Raschle**[5] | **Evelyn Herbrecht**[1] | **Christina Stadler**[1] | **Ana Cubillo**[1]

[1]Child and Youth Psychiatry, University Psychiatric Clinic, Basel, Switzerland

[2]Child and Youth Psychiatry, Psychiatric University Clinic, University of Zurich, Zurich, Switzerland

[3]Donders Institute for Brain, Cognition and Behaviour, Radboud University, and Radboud University Medical Centre, Nijmegen, the Netherlands

[4]Psychology of Language Department, Max Planck Institute for Psycholinguistics, Nijmegen, the Netherlands

[5]Jacobs Center for Productive Youth, University of Zurich, Zurich, Switzerland

[6]Translational Psychiatry, University Psychiatric Clinic, Basel, Switzerland

**Correspondence**
Antonia Tkalcec, Child and Youth Psychiatry, University Psychiatric Clinic, Basel, Switzerland.
Email: antonia.tkalcec@upk.ch

**Funding information**
Schweizerischer Nationalfonds zur Förderung der Wissenschaftlichen Forschung, Grant/Award Number: 100014_185408/1

## Abstract

Distinct empathy deficits are often described in patients with conduct disorder (CD) and autism spectrum disorder (ASD) yet their neural underpinnings and the influence of comorbid Callous-Unemotional (CU) traits are unclear. This study compares the cognitive (CE) and affective empathy (AE) abilities of youth with CD and ASD, their potential neuroanatomical correlates, and the influence of CU traits on empathy. Adolescents and parents/caregivers completed empathy questionnaires ($N = 148$ adolescents, mean age $= 15.16$ years) and T1 weighted images were obtained from a subsample ($N = 130$). Group differences in empathy and the influence of CU traits were investigated using Bayesian analyses and Voxel-Based Morphometry with Threshold-Free Cluster Enhancement focusing on regions involved in AE (insula, amygdala, inferior frontal gyrus and cingulate cortex) and CE processes (ventromedial prefrontal cortex, temporoparietal junction, superior temporal gyrus, and precuneus). The ASD group showed lower parent-reported AE and CE scores and lower self-reported CE scores while the CD group showed lower parent-reported CE scores than controls. When accounting for the influence of CU traits no AE deficits in ASD and CE deficits in CD were found, but CE deficits in ASD remained. Across all participants, CU traits were negatively associated with gray matter volumes in anterior cingulate which extends into the mid cingulate, ventromedial prefrontal cortex, and precuneus. Thus, although co-occurring CU traits have been linked to global empathy deficits in reports and underlying brain structures, its influence on empathy aspects

Antonia Tkalcec and Maria Bierlein should be considered joint first author.

Christina Stadler and Ana Cubillo should be considered joint senior author.

might be disorder-specific. Investigating the subdimensions of empathy may therefore help to identify disorder-specific empathy deficits.

**Lay Summary**

To improve our understanding of empathy deficits in autism spectrum disorder (ASD) and conduct disorder (CD) youths, we measured the main empathy aspects affective (AE) and cognitive empathy (CE) using reports and underlying brain structures. While both disorders show overlapping empathy deficits, disorder-specificities can be found when accounting for the influence of co-occurring Callous-Unemotional (CU) traits.

**KEYWORDS**

autism spectrum disorder, brain structure, conduct disorder, Callous-Unemotional traits, empathy

# BACKGROUND

Empathy is the ability to understand another person's mental state and respond with an appropriate emotion (Decety & Jackson, 2004), and is essential to social functioning (de Vignemont & Singer, 2006; de Waal & Preston, 2017; Eisenberg et al., 2014; Uzefovsky & Knafo-Noam, 2016; Walter, 2012). Affective (AE) and cognitive (CE) empathy are described as the two main aspects of empathy (Dvash & Shamay-Tsoory, 2014; Walter, 2012). AE is the ability to feel another person's emotion and respond with an appropriate emotional reaction (Baron-Cohen & Wheelwright, 2004) and includes experiencing personal distress due to the distress of others (Eisenberg, 2010; Uzefovsky & Knafo-Noam, 2016). CE includes Theory of Mind (TOM) or perspective taking (Uzefovsky & Knafo-Noam, 2016) and comprises the accurate recognition, understanding, and mentalization of the emotions and cognitions of others (Baron-Cohen & Wheelwright, 2004). Adaptive social behavior requires the interplay between AE and CE processes, with deficits in one of these aspects potentially leading to substantial impairments in social behaviors (Preckel et al., 2018).

Selective impairments in AE and CE have been observed in different psychological disorders such as patients with autism spectrum disorder (ASD) or conduct disorder (CD). Empathy deficits are a known core feature of ASD experiencing major difficulties in perspective-taking (Vilas et al., 2021), TOM (Baron-Cohen et al., 1985; Blair, 2005; Cantio et al., 2016; Happé et al., 2017; Jones et al., 2010; Schwenck et al., 2012) and social interaction (Frith & Frith, 2003; van der Zee & Derksen, 2020). Patients with ASD frequently show difficulties in emotion recognition and distinguishing between positive and negative facial expressions, which might lead to deficits in appropriate social responding and social reciprocity (Frith, 2001; Schulte-Rüther et al., 2017). Theories like the Empathy Imbalance (Rogers et al., 2007; Schwenck et al., 2012; Smith, 2006, 2009) suggest that youth and adults with ASD (Gillespie-Lynch et al., 2017; Lombardo et al., 2016; Rogers et al., 2007; Schwenck et al., 2012; Shalev et al., 2022; Smith, 2006, 2009), and neurotypicals with elevated autistic traits (Shalev & Uzefovsky, 2020) would display deficits in understanding others' emotions (CE) and a surfeit in AE, while others suggest a more global empathy deficit including AE and CE (Grove et al., 2014). By contrast, the available evidence for youth with CD suggests that AE would be impaired while CE is not (Blair, 2013; Blair et al., 2014; Igoumenou et al., 2017). Children and youth with CD are typically characterized by repetitive and persistent behaviors of violations of others' rights, theft, lying, violence, and reckless breaking of rules (American Psychiatric Association, DSM-5 Task Force, 2013; Frick & Nigg, 2012). CD poses a significant burden at the individual, social and economic levels (Erskine et al., 2014, 2016; Foster et al., 2005). It also presents heightened risks for comorbid disorders (Angold et al., 1999; Erskine et al., 2016; Foster et al., 2005; Loeber et al., 2009; Odgers, 2009), which often persists into adulthood (Fairchild et al., 2019; Simonoff et al., 2004). Youth with CD and high callous-unemotional (CU) traits show a distinctive developmental pathway (Frick & Kemp, 2021) typically displaying more severe, aggressive, and persistent antisocial behaviors (Fontaine et al., 2011; Frick et al., 2003; Lawing et al., 2010; McMahon et al., 2010; Waller & Hyde, 2018; Willoughby et al., 2014). CU traits, defined by low empathy, guilt, and prosociality (Fairchild et al., 2019), have been associated with AE and empathy deficits in relation to antisocial and psychopathic behaviors (Burghart & Mier, 2022; Campos et al., 2022; Jones et al., 2010; Martin-Key et al., 2017; Waller et al., 2015), and are considered a risk factor for the development of psychopathy in adulthood (Hyde & Dotterer, 2022). Some evidence suggests the potential presence of a double dissociation in the CE/AE empathy deficits observed in ASD and CD adolescents with high CU traits, respectively (Chen et al., 2016; Jones et al., 2010; Lockwood et al., 2013; Pijper et al., 2016; Schwenck et al., 2012). However, a recent meta-analysis did not observe differences in association strength between CU traits and AE or CE (Waller, Wagner, et al., 2020) implying that CU traits might rather be linked with global empathy. Interestingly, although CU traits have been primarily linked to CD, CU traits and ASD are both characterized by disruptive behaviors and reduced empathic responsiveness (American Psychiatric Association, DSM-5 Task Force, 2013), and often co-occur in children with ASD (Carter Leno et al., 2021). Thus, CU traits might present a potential symptomatic overlap between ASD and CD (Carter Leno et al., 2015, 2021; Frick et al., 2013; Herpers et al., 2016; Ibrahim et al., 2019; Kaat & Lecavalier, 2013). An improved understanding on the association between CU traits and the empathy deficits observed in ASD and CD and could potentially help would be needed to test whether these deficits really show a double dissociation character (Georgiou et al., 2019; Grove et al., 2014; Klapwijk et al., 2016; Noppari, 2022; Vilas et al., 2021).

Brain imaging studies have shown CE processes to be more strongly supported by cortical regions whereas AE processes would be supported by neural networks with more significant involvement of subcortical and limbic regions (Bernhardt & Singer, 2012; Bray et al., 2022; Bzdok et al., 2012; Fan et al., 2011; Frith & Frith, 2003; Lamm et al., 2011; Schurz et al., 2014; Stern et al., 2019; Uribe et al., 2019; Van Overwalle & Baetens, 2009). Thus, taking the neural correlates of a potential double dissociation in empathy deficits into account, ASD would be expected to show neural abnormalities in cortical regions involved in CE processes, and youth with CD in subcortical and limbic regions involved in AE processes. The evidence is however inconsistent (Klapwijk et al., 2016; Noppari, 2022). In a recent meta-analysis, ASD youth displayed gray matter volume (GMV) decreases in limbic regions including temporal cortex and amygdala, linked to processes underlying AE (Marsh, 2018), compared with typically developing youth (TD) (Del Casale et al., 2022). Youth with CD, have meanwhile shown reduced GMV across cortical regions including the anterior cingulate cortex (ACC), ventromedial prefrontal cortex (vmPFC), temporal cortex and anterior Insula (AI), as well as subcortical structures (Fairchild et al., 2019; Rogers & De Brito, 2016; Sebastian et al., 2016). The precise contribution of these regions to the observed empathy deficits is yet to be determined (Fan et al., 2011; Gothard, 2020; Mutschler et al., 2013; Šimić et al., 2021; Walter, 2012). Compared to healthy participants, adults who were criminal offenders with psychopathic traits displayed lower GMV in the insula, frontal cortex and sensorimotor cortex while adults with ASD showed reduced GMV in left precuneus (PCu) and cerebellum (Noppari, 2022). Furthermore, both groups shared structural alterations in the right precentral gyrus compared with a healthy control group, which has been linked to AE processes (Bray et al., 2022; Kim et al., 2020; Naor et al., 2020). In direct comparisons, the offender group showed lower GMV in the left temporal pole and left inferior frontal gyrus (IFG) than the ASD group (Noppari, 2022). These results therefore suggest the potential presence of both shared and disorder-specific and shared structural differences underlying AE and CE deficits shown by patients with ASD and patients with psychopathic traits. These results would be in line with findings in a comparison study on brain function revealing shared reduced responses during an emotion contagion task, which is linked to AE, in the amygdala, but differ in their functional alterations from controls during an emotion recognition task, linked to CE processes (Klapwijk et al., 2016).

Differences linking specific empathy deficits to structural neural correlates in youth with ASD or CD have not yet been investigated. The direct comparison of potential disorder-specific differences in brain structure and their association with empathy deficits in neurodevelopmental disorders acquires particular relevance during adolescence. This is due to the crucial neural developmental processes that still undergoing during this period. Together with pubertal changes and potential stressors related among others to social factors, this makes of adolescence a period of particular vulnerability to the appearance or exacerbation of psychiatric symptoms (Blakemore, 2012; Di Martino et al., 2014; Dumontheil, 2016; Fuhrmann et al., 2015).

In sum, the specificity of the empathy deficits observed in ASD and CD and their underlying brain structural correlates are not yet well understood. Such studies might provide additional insight into differences between CD and ASD in AE/CE measured as a trait and might help to close the knowledge gap on the disorders' neurodevelopmental specificities. This might help in defining overlapping and distinctive empathy aspects and disorder-specific deficits which might consequently support efforts towards a consensus in the empathy concept definition. Additionally, the compared influence of CU traits on possible associations of reported measures and brain structures in both ASD and CD has not yet been investigated. This study investigates the potential dissociation in empathy deficits in youths with CD and ASD and their neuroanatomical underpinnings expecting that CU traits show a stronger impact on the CD than ASD group based on its primary link to this disorder (American Psychiatric Association, DSM-5 Task Force, 2013). We used measures from self- and parent-reports to overcome the limitation of previous studies investigating empathy mainly using either parent-or caregiver-reports for children or self-reports for adolescents (Sesso et al., 2021). Additionally, we use structural brain imaging to identify the potential differences in neural structures underlying the empathy deficits observed in these populations. We hypothesize that, compared with TD, patients with CD display lower scores in AE and lower GMV in regions involved in AE processes (CD < ASD, TD), while patients with ASD show lower scores in CE and lower GMV in regions involved in CE processes (ASD < CD, TD). We also want to determine to what extent CU traits are related to AE and/or CE and associated brain structures in CD and ASD and whether there are group differences in this association.

# METHODS

## Participants

Adolescent participants with ASD and CD were recruited from different specialized clinical settings and residential centers in Basel and Zurich (University Psychiatric Clinic in Basel, Psychiatric University Clinic in Zurich, AHBasel foundation, and youth home Schlössli in Basel). Participants included in the TD group were recruited from socioeconomically diverse secondary schools in the Canton Basel-Stadt. Inclusion criteria for children and adolescents within the patient's group were the fulfillment of the DSM-5 diagnostic criteria (American Psychiatric Association, DSM-5 Task Force, 2013) for either CD or ASD and no comorbid depressive or anxiety disorder. To be included in the TD group, participants could not meet the criteria for any current or previous psychiatric disorder. Clinical assessment of the diagnostic criteria was conducted using a semi-structured clinical interview (Schedule for Affective Disorders and Schizophrenia for School-Age Children – Present and Lifetime Version, K-SADS-PL) (Kaufmann et al., 1997) for all participants. For the ASD group, the ADOS or ADI-R (Bölte et al., 2006; Poustka et al., 2015) was additionally administered. Additional inclusion criteria were an average IQ score (>70) for all participants. Consequently, this entailed that for the ASD group diagnostic criteria for either Asperger's syndrome or high functioning autism had to be fulfilled. When IQ test results were available from the clinics which were no older than 24 months prior to study enrollment, then information was entered into our database. When such information was not available or results were older than 24 months, a psychometric IQ assessment using Wechsler Intelligence Scale For Children (WISC-IV) (Wechsler, 2012b) or Wechsler Adult Intelligence Scale (WAIS-IV) (Wechsler, 2012a) was conducted. Participants and caregivers/parents filled out different questionnaires. Participants completed the Basic Empathy Scale (BES) (Jolliffe & Farrington, 2006), whereas parents/ caregivers completed the Griffith Empathy Measure (GEM) (Dadds et al., 2008). Both questionnaires provide subscale scores of AE and CE. In addition, caregivers filled out the Inventory of Callous Unemotional traits (ICU) (Frick, 2017). Participants then underwent a structural brain imaging data acquisition session. Written informed assent and/or consent was obtained from participants and caregivers.

The total sample included 163 participants, with $N_{CD} = 76$, $N_{ASD} = 40$, and $N_{TD} = 47$. However, 15 participants had to be excluded due to missing data ($N_{CD} = 7$; $N_{ASD} = 7$; $N_{TD} = 1$). Thus, the final sample with valid psychometric data consisted of 148 participants, with $N_{CD} = 69$, $N_{ASD} = 33$ and $N_{TD} = 46$ youth aged 10–18 years ($M = 15.24$; $SD = 2.12$ years). For the MRI analysis, data from 18 participants had to be additionally excluded due to missing/low-quality data or incidental findings ($N_{CD} = 11$, $N_{ASD} = 6$, $N_{TD} = 1$). Thus, valid brain imaging data was available for a subset of 130 participants ($N_{CD} = 58$; $N_{ASD} = 27$; $N_{TD} = 45$). Given that the data was collected in two waves with the first wave collecting data from a total of 61 participants ($N_{CD} = 23$; $N_{ASD} = 3$; $N_{TD} = 35$) and the rest being collected in the second wave, we included data collection wave as an additional regressor of no interest in all questionnaire and brain imaging analyses to account for potential differences in the version of the MRI operating system and changes in the structure of the research team or other potential differences during data collection. Further details on the sample characteristics are shown in Table 1.

## Analysis of self-and parent-reported empathy questionnaires

All behavioral analyses were conducted using R (Version 4.2.1) (R Core Team, 2020) and RStudio (Version 2022.7.0.547) (RStudio Team, 2022). From the whole dataset, 5% of participants did not have a valid record of IQ data, 5% of participants had missing responses in the BES questionnaire, 18% in the GEM questionnaire, and 17% in the ICU questionnaire. Following standard recommendations, imputation of missing data is practicable for variables missing at random, using the "mice" package to implement multiple imputation by chained equations (van Buuren & Groothuis-Oudshoorn, 2011) (m = 100, maxit = 20, meth = "pmm") to maximize the data used for those analyses. Details on the missing data for each variable are shown in Table 1.

We examined the presence of group differences in the affective and cognitive subscales of the BES and GEM using four regression models within a Bayesian framework, with the group values entered as the main regressor of interest and empathy scores as the dependent variables. Age, sex, IQ, and data collection wave were also included as regressors of no interest to account for potential developmental and group differences in these dimensions (Table 1). All variables were z-scored before being entered in the analyses. The regression included a flat prior and a Gaussian likelihood distribution, with parameters warmup = 1000, iter = 2000, 3 chains, and 3 cores. Since CU traits have shown to be significantly negatively correlated with empathic abilities, especially in antisocial youth (Waller, Wagner, et al., 2020) two additional separate models were created including CU traits either as a regressor or in interaction with the variable group. For this, z-scores were calculated from the total sum score of

**TABLE 1** Sample characteristics.

| | ASD ($N = 33$) | | CD ($N = 69$) | | TD ($N = 46$) | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean (SD)/ count (%) | NR missing values | Mean (SD)/ count (%) | NR missing values | Mean (SD)/ count / %) | NR missing values | Chi square/F stat | *p* value |
| Sex | 12F/21M | 0 | 16F/53M | 0 | 23F/23M | 0 | 8.85 | 0.01 |
| Age (Years) | 14.97 (2.57) | 0 | 15.61 (1.81) | 0 | 14.89 (2.16) | 0 | 1.96 | 0.15 |
| IQ | 106.24 (14.21) | 0 | 96.78 (11.08) | 4 | 103.46 (8.27) | 4 | 9.79 | <0.001 |
| AE GEM | −5.97 (15.61) | 1 | 1.29 (13.44) | 24 | 1.96 (11.92) | 2 | 4.01 | 0.02 |
| CE GEM | 0.52 (10.06) | 1 | 5.14 (9.19) | 24 | 10.85 (8.29) | 2 | 12.74 | < 0.001 |
| Total GEM | −2.91 (27.61) | 1 | 15.19 (24.63) | 24 | 23.28 (22.87) | 2 | 10.96 | <0.001 |
| AE BES | 34.42 (7.83) | 1 | 34.22 (6.17) | 3 | 38 (6.51) | 4 | 4.93 | 0.01 |
| CE BES | 30.36 (7.33) | 1 | 36.29 (5.29) | 3 | 36.78 (4.07) | 4 | 15.83 | <0.001 |
| Total BES | 63.79 (13.87) | 1 | 70.55 (9.47) | 3 | 74.98 (9.01) | 4 | 10.97 | <0.001 |
| ICU sum | 28.33 (10.60) | 1 | 28.84 (9.29) | 23 | 17.07 (8.06) | 2 | 25.05 | <0.001 |
| ADHD | 7 (21.21%) | 0 | 30 (43.48%) | 0 | 0 | 0 | 28.15 | <0.001 |
| ODD | 2 (6.06%) | 0 | 12 (26.08%) | 0 | 0 | 0 | 18.09 | <0.001 |
| Addictive disorders | 0 | 0 | 19 (27.54%) | 0 | 0 | 0 | 24.96 | <0.001 |
| PTSD | 2 (6.06%) | 0 | 15 (21.74%) | 0 | 0 | 0 | 14.06 | <0.001 |
| Tic disorders | 1 (3.03%) | 0 | 1 (1.45%) | 0 | 0 | 0 | 1.33 | 0.51 |
| Bulimia Nervosa | 0 | 0 | 1 (1.45%) | 0 | 0 | 0 | 1.15 | 0.56 |

*Note*: This table shows the mean and standard deviation (SD) or number count and percentage (%) for each group as well as the group differences for the key demographic variables and questionnaire scores utilized in the present study. For each variable and within each group, the number of participants with missing values for the corresponding value is shown. Missing values were imputed using the MICE package in R with 5000 imputations using all available data for those participants used in the present study. Group comparisons were conducted after imputation and do not differ from those before the imputation. Except for age, comorbid Tic disorders and Bulimia Nervosa, at least one group differed significantly in all other variables.

Abbreviations: ADHD, attention deficit hyperactivity disorder; Addictive disorders, substance or alcohol abuse/dependency disorder; AE/CE BES, affective/cognitive empathy score of the basic empathy scale; AE/CE GEM, affective/cognitive empathy subscale sum of the griffith empathy measure (GEM); ASD, patients with autism-spectrum disorder diagnosis; CD, patients with conduct disorder diagnosis; ICU sum, total sum score of inventory for callous unemotional traits (ICU) (Frick, 2017); IQ, intelligence quotient (total score of WASI, WISC or WAIS); ODD, oppostional defiant disorder; TD, typically developing youth; Tic, Tic disorders; Total GEM/BES, total sum score of the griffith empathy measure/basic empathy scale; PTSD, post-traumatic stress disorder.

the Inventory of Callous Unemotional traits (ICU) (Frick, 2017). Then, all three models were compared using the leave-one-out cross validation (LOO) method, which uses the log-likelihood computed by $n$ (as size of the dataset) posterior simulations with one sample as the test set and the rest being the training set for the model (Vehtari et al., 2017).

## Structural MRI acquisition and analyses

Brain structural images were acquired using a Siemens 3.0 Tesla Prisma scanner at the University Hospital Basel. The acquired T1-weighted structural magnetization prepared rapid gradient echo (MPRAGE) images included 192 slices, field of view 256 mm, voxel size $1 \times 1 \times 1$mm, repetition time 1900 ms, echo time 3.42 ms. Customized TPMs and DARTEL templates to represent the whole sample were generated within the Cerebromatic toolbox (COM) (Wilke et al., 2017), an updated version of TOM8 using a more flexible approach (Wilke et al., 2017). Therefore, information about age, sex, and field strength of the 130 participants was used to create priors of the population of interest based on the regression parameters provided by the University of Tuebingen.

In line with previous studies (Del Casale et al., 2022; Fairchild et al., 2019; Noppari, 2022; Rogers & De Brito, 2016; Sebastian et al., 2016), GMV was used as brain structural measure as it takes into account influences of cortical volume subcomponents such as cortical thickness or surface areas (Vijayakumar et al., 2018) including their different developmental trajectories (Mills et al., 2016). Thus, GMV allows us to relate the findings with the available evidence in the literature.

Voxel-Based Morphometry (Ashburner & Friston, 2000) analysis was conducted using CAT12 (Computational Anatomy Toolbox) (Gaser & Dahnke, 2016), implemented in SPM12 (Statistical Parametrical Mapping) (Penny et al., 2006). After individual inspection of raw data, preprocessing was conducted following the standard steps as recommended in the CAT2 manual. Next, we manually inspected the quality reports by CAT12, (providing parameters of noise, inhomogeneities, and image resolution) for each T1 image. Only those individuals whose data quality was classified as C- or higher were included in the analyses, representing satisfactory image quality (https://neuro-jena.github.io/cat/index.html#QC). Consequently, $N = 3$ participants had to be excluded due to quality issues. To correct for differences in brain size and volume, Total Intracranial Volumes (TIV) were calculated for each participant with CAT12 and added to the analyses as a regressor of no interest.

### Region of interest (ROI) statistical analyses

To investigate the association and potential group differences between GMV and AE and CE, we created two general linear models for the GEM and the BES, including group as factor and both empathy subscales as regressors. The simultaneous consideration of both empathy subscales differs from the analyses in 2.2 and is justified by previous separate analyses whose results did not differ from the present one. Next, two additional models were created to investigate the potential associations between CU traits and GMV, by adding ICU total scores as an additional regressor to the previous models. Further models were designed to examine group differences in the association between empathy respectively CU traits and GMV (group × empathy; group × CU), as well as the interaction of CU traits and empathy associated with GMV (CU × empathy), with the product of empathy and CU trait scores as a new regressor. Separate interaction models were created with each of them including both empathy subscales for the corresponding questionnaire. For all models, the normalized individual images were included in a full factorial anova, with IQ, age, sex and TIV as regressors of no interest. As described in Section 2.1, an additional regressor was included to account for potential differences related to the data collection wave.

We restricted the analyses to regions previously associated with CE and AE (Bray et al., 2022; Fan et al., 2011; Schurz et al., 2014; Stern et al., 2019). To do so, we created a combined mask of regions associated with AE (amygdala, insula, IFG, cingulate cortex), and CE processes (vmPFC, TPJ, superior temporal gyrus, and PCu), using FSL eyes (Version 1.3.0) (https://zenodo.org/record/7038115#.Y9Kly8hKiUc) choosing from the Harvard Oxford Atlas, and xjView (Version 10.0) (https://www.alivelearn.net/xjview/) (Figure S1). Significant results at $p < 0.05$ were identified via the generation of a null distribution over 5000 permutations, followed by a Threshold-Free Cluster Enhancement (TFCE) technique along with family-wise error (FWE) correction for comparison across multiple voxels. TFCE identifies cluster-like patterns by considering voxel- and cluster-related information without relying on fixed statistics for cluster-definition thresholds, thus computing significant clusters that retain voxel-wise weightings (Smith & Nichols, 2009).

## RESULTS

### Construct evaluation

Spearman correlations were conducted in R to identify the underlying correlations between the corresponding subscales of the two questionnaires (i.e., cognitive subscale in the self-report and cognitive subscale in the parent-report questionnaire). Each empathy subscale of the self-report showed a small correlation with each of the counterpart subscales of the parent-report (CE in BES × GEM: $rho = 0.16$, $p = 0.05$; AE in BES × GEM: $rho = 0.25$, $p < 0.001$) (Table S1a). To further investigate potential differences in this matter between groups, correlations were conducted for each of the groups separately. Results display low correlations for AE ($rho > 0.3$, $p < 0.001$) in the ASD and the TD group and non-significant correlations for AE in the CD group (Table S1b). Non-significant CE correlations were found between questionnaires across all groups (Table S1b).

### Questionnaire results

Multiple linear regressions within a Bayesian framework without CU traits included in the models revealed significant results for the variable group in most combinations of empathy and questionnaire type (Table 2). In the self-report (BES), the ASD group reported significantly lower scores in CE compared to the TD and CD groups while no significant difference was found between the CD and TD group (Table 2). In the parent-report (GEM), the ASD group showed lower AE and CE scores than the TD and CD groups and the CD group displayed lower CE scores than the TD group. Model comparisons revealed that the majority preference lies with the models that include CU traits as a covariate (Table 3). However, a better model fit cannot be completely determined because of low standard errors. Although the interaction of group and CU traits was the preferred model in the parent-reported CE subscale (GEM), this was not the case for parent-reported AE (GEM) and self-reported AE and CE (BES) (Table 3). With the inclusion of CU traits as a covariate in the models, the CD group no longer significantly differed from the TD group in parent-reported CE. For patients with ASD, group differences were reduced for AE in the parent-report but remained for CE in both self-and parent-reports (Table 4). Additional supplementary analyses were conducted including the interactions of group and CU traits (Table S2), age (Table S3), sex (Table S4), and discrepancy measures for both empathy questionnaires (Table S5). Results showed

**TABLE 2** Bayesian regression analysis for self- and parent-reports on AE/CE.

| | Self-report | | | | | Parent-report | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Affective empathy** | | | | | | | | | | |
| **Hypothesis** | **Est.** | **SE** | **95% CI** | | **Post. Prob.** | **Est.** | **SE** | **95% CI** | | **Post. Prob.** |
| ASD < TD | −0.15 | 0.25 | −0.56 | 0.25 | 0.27 | −0.46 | 0.27 | −0.9 | −0.03 | 0.04 |
| CD < TD | −0.24 | 0.19 | −0.56 | 0.07 | 0.1 | −0.05 | 0.22 | −0.41 | 0.3 | 0.6 |
| ASD > CD | 0.1 | 0.22 | −0.26 | 0.46 | 0.33 | −0.5 | 0.25 | −0.91 | −0.11 | 0.02 |
| **Cognitive empathy** | | | | | | | | | | |
| **Hypothesis** | **Est.** | **SE** | **95% CI** | | **Post. Prob.** | **Est.** | **SE** | **95% CI** | | **Post. Prob.** |
| ASD < TD | −0.92 | 0.24 | −1.31 | −0.53 | 0 | −1.11 | 0.24 | −1.51 | −0.71 | 1 |
| CD < TD | −0.06 | 0.2 | −0.37 | 0.27 | 0.39 | −0.57 | 0.19 | −0.88 | −0.25 | 0 |
| ASD < CD | −0.85 | 0.22 | −1.21 | −0.49 | 0 | −0.54 | 0.23 | −0.92 | −0.17 | 0.01 |

*Note*: This table shows the multiple regression analysis results testing the one-sided hypotheses on key dependent variables: AE and CE subscale scores of self-reports (BES) (Jolliffe & Farrington, 2006) and parent-reports (GEM) (Dadds et al., 2008). All models included the following regressors: group, age, IQ, sex, data collection wave. The variable CU traits was created using z-scores of the total sum of the Inventory of Callous Unemotional traits (ICU) (Frick, 2017). All included variables were z-scored. Results show lower CE/AE scores for the ASD group compared to the TD group in the parent-report. Compared to the CD group, the ASD group shows lower CE scores in self-and parent-reports, and lower AE scores in the parent-report. The CD group shows lower CE scores in the parent-report when compared to the TD group.
Abbreviations: 95% CI, credible interval; ASD, youth with autism spectrum disorder; CD, youth with conduct disorder; Est., estimate; Hypothesis, direction of tested hypothesis; Post. Prob., posterior probability under the hypothesis against the hypothesis' alternative; SE, standard-error; TD, typically developing youth.

**TABLE 3** Model comparison using leave-one-out cross validation method among models with and without CU traits as covariate and in interaction with group.

| **Affective empathy** | | | | | |
|---|---|---|---|---|---|
| **Model** | **elpd_diff** | **se_diff** | **Model** | **elpd_diff** | **se_diff** |
| CU as cov. | 0 | 0 | CU as cov. | 0 | 0 |
| Basic model | −1.7 | 2.1 | Interaction CU × Group | −0.6 | 1.9 |
| Interaction CU × Group | −2 | 1.1 | Basic model | −1.8 | 2.8 |
| **Cognitive empathy** | | | | | |
| **Model** | **elpd_diff** | **se_diff** | **Model** | **elpd_diff** | **se_diff** |
| CU as cov. | 0 | 0 | Interaction CU × Group | 0 | 0 |
| Basic model | −0.6 | 2.2 | CU as cov. | −0.6 | 2 |
| Interaction CU × Group | −1.8 | 1.2 | Basic model | −6.1 | 4 |

*Note*: This table shows the model comparison results of leave-one-out cross validation as information criteria on key dependent variables of the multiple regression analysis: AE and CE subscale scores of self-reports (BES, Jolliffe & Farrington, 2006) and parent-reports (GEM, Dadds et al., 2008). The basic model (=*Basic model*) included the following regressors: group, age, IQ, sex and data collection wave. Additionally, one model included CU traits as covariate (=*CU as cov.*), and another model an interaction of CU traits and group (=*Interaction CU × group*). The variable CU traits was created using z-scores of the total sum of the Inventory of Callous Unemotional traits (ICU) (Frick, 2017). All included variables were z-scored. Results show the pairwise comparisons between each model and the model with the largest ELPD. The preference lies with the model including CU traits as covariate in the model for AE subscale scores of self-and parent-reports and CE subscale scores of the self-reports. For CE, in the parent-report the model including the interaction of CU traits and group is preferred over the other models.
Abbreviations: elpd diff, expected log pointwise predictive density; se diff, standard error; CU, callous-unemotional traits.

negative main effects of sex on self-reported AE, and main and interaction effects on AE discrepancy measures. Age and group revealed a positive interaction effect for the ASD group in self-reported AE.

## Structural MRI results

Within the regions of interest, we observed no significant group effects or effects of AE or CE on GMV in either of the two models including group as factor and both empathy scales of either the GEM or the BES and regressors. The two models that additionally included the ICU score as regressor, however, revealed significant negative associations with GMV for both questionnaires GEM and BES with overlapping clusters in the left ACC extending into mid-cingulate (MCC) and the vmPFC, and PCu (peak MNI = 3; 31; −15, 32,457 $mm^3$ volume), with all p(FWE) <0.05 (Figure 1, Table 5). Significant clusters for both models including either empathy scores of the BES or the GEM do not substantially differ between them. Separate results for both models are displayed in Table S6. No significant interaction effect was observed.

**TABLE 4** Bayesian regression analysis for self - and parent-reports on AE/CE including CU traits as regressor in the model.

| | Self-report | | | | | Parent-report | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Affective empathy** | | | | | | | | | | |
| **Hypothesis** | **Est.** | **SE** | **95% CI** | | **Post. Prob.** | **Est.** | **SE** | **95% CI** | | **Post. Prob.** |
| ASD < TD | 0.04 | 0.26 | −0.4 | 0.46 | 0.56 | −0.22 | 0.28 | −0.68 | 0.23 | 0.22 |
| CD < TD | −0.05 | 0.21 | −0.4 | 0.29 | 0.41 | −0.3 | 0.22 | −0.68 | 0.07 | 0.92 |
| ASD > CD | 0.09 | 0.21 | −0.25 | 0.44 | 0.34 | −0.51 | 0.23 | −0.9 | −0.13 | 0.01 |
| **Cognitive empathy** | | | | | | | | | | |
| **Hypothesis** | **Est.** | **SE** | **95% CI** | | **Post. Prob.** | **Est.** | **SE** | **95% CI** | | **Post. Prob.** |
| ASD < TD | −0.73 | 0.26 | −1.15 | −0.31 | 0 | −0.78 | 0.25 | −1.19 | −0.37 | 1 |
| CD < TD | 0.12 | 0.21 | −0.22 | 0.46 | 0.72 | −0.23 | 0.21 | −0.56 | 0.11 | 0.13 |
| ASD < CD | −0.86 | 0.22 | −1.22 | −0.51 | 0 | −0.57 | 0.22 | −0.92 | −0.2 | 0.01 |

*Note*: This table shows the multiple regression analysis results testing the one-sided hypotheses on key dependent variables: AE and CE subscale scores of self-reports (BES) (Jolliffe & Farrington, 2006) and parent-reports (GEM) (Dadds et al., 2008). All models included the following regressors: group, age, IQ, sex, data collection wave and CU traits. The variable CU traits was created using z-scores of the total sum of the Inventory of Callous Unemotional traits (ICU) (Frick, 2017). All included variables were z-scored. Results show group differences in the CE aspects for both self- and parent-reports with the ASD group showing lower scores compared to the TD and CD group. Both CD and ASD groups do not significantly differ in AE scores from the TD group, but the ASD group shows lower scores than the CD group in parent-reported AE.

Abbreviations: 95% CI, credible interval; ASD, youth with autism spectrum disorder; CD, youth with conduct disorder; Est., estimate; Post. Prob., posterior probability under the hypothesis against the hypothesis' alternative; SE, standard-error.

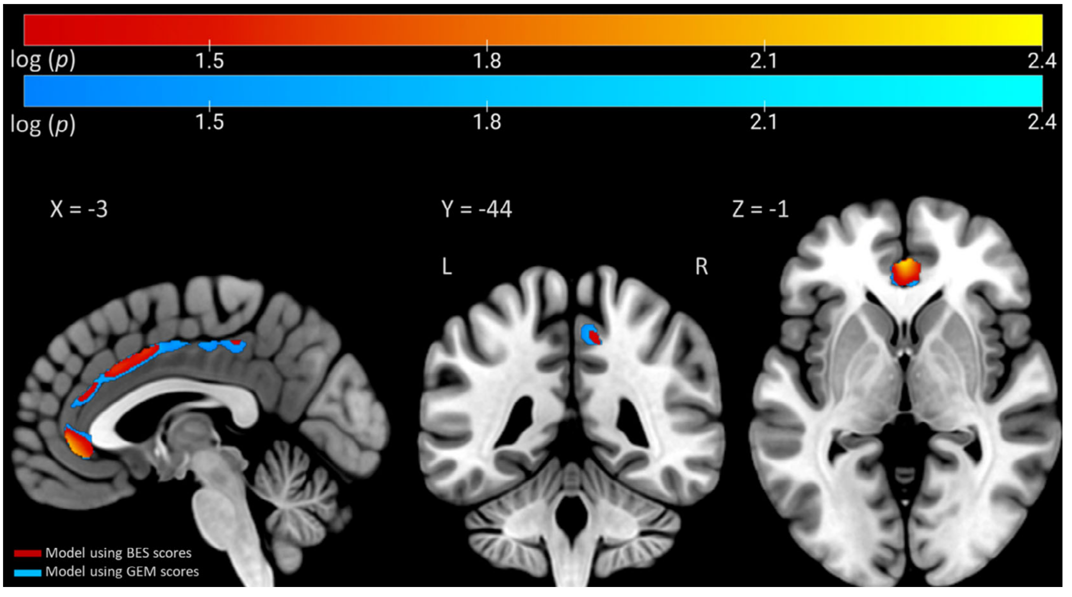


**FIGURE 1** This figure shows the overlap of the full factorial analyses results including AE and CE of either the BES or GEM, CU traits and group as regressors of interest and TIV, age, sex, data collection wave and IQ as regressors of no interest. Colored clusters depict the voxels significantly negatively associated with CU traits, with blue clusters representing results from the model including empathy scores of the GEM, while red clusters depict results of the model including empathy scores of the BES. Across all participants, significant associations were observed between GMV and CU traits in the left ACC, extending into the MCC and vmPFC, as well as the PCu. Results for both models do not differ substantially from each other (peak MNI = 3; 31; −15, 32,456 $mm^3$ volume), with all p(FWE) < 0.05. ACC, anterior cingulate cortex; AE, affective empathy; BES, basic empathy scale; CE, cognitive empathy; CU, callous-unemotional traits; FWE, familywise error rate; GEM, griffith empathy measure; GMV, gray matter volume; IQ, intelligence quotient; MCC, mid cingulate cortex; MNI, montreal neurological institute; PCu, precuneus; TIV, total intracranial volume; vmPFC, ventromedial prefrontal cortex.

For completeness, we conducted whole brain analyses (Figure S2) whose results do not differ significantly from the main ROI described above with exception of the additional cluster in the orbitofrontal pole, that was negatively associated with CU traits in the BES (Figure S2 and Table S7). An additional region of interest analysis of GMV was conducted to examine possible structural differences in youths with low versus high levels of CU traits based on the clinical cutoff score of 30 in the ICU questionnaire, as recommended by Docherty et al.

**TABLE 5** Spatial centers of gravity depicting the shared peak clusters of the region of interest analysis negatively associated with callous-unemotional traits.

| Structures | Volume | Spatial centers of gravity | | |
|---|---|---|---|---|
| | | X | Y | Z |
| Medial orbitofrontal cortex (R), Anterior cingulate (L,R) | 1452 | 1 | 39 | −1 |
| Anterior cingulate (L), Mid-cingulate (L, R) | 1039 | −3 | 13 | 37 |
| Mid-cingulate (L) | 594 | −8 | −25 | 42 |
| Anterior cingulate (L,R) | 246 | −1 | 35 | 22 |
| Precuneus (R), Mid-cingulate (R) | 167 | 11 | −43 | 48 |

*Note*: This table depicts the spatial centers of gravity of binary clusters significantly negatively associated with CU traits that were created by combining regions that were significant in both models. Regressions for the separate models included group as factor, AE and CE of either the self-reported BES or the other-reported GEM, and total CU trait scores as regressors, as well as IQ, age, sex, data collection wave, and TIV as covariates. All included variables were z-scored. Results were estimated using TFCE, FWE-corrected, and thresholded at $p < 0.05$. Across all participants and for both models, significant associations were observed between GMV and CU traits in the left ACC, extending into the vmPFC and the MCC, as well as the PCu. As can be seen in Table S2 significant clusters for both models including empathy scores of either the BES or the GEM do not differ substantially from each other.

Abbreviations: AE, affective empathy; BES, basic empathy scale; CE, cognitive empathy; CU, callous-unemotional traits; FWE, family-wise error correction for multiple comparisons; GEM, griffith empathy measure; IQ, intelligence quotient; L, left; MNI, montreal neurological institute; R, right; TFCE, threshold free cluster enhancement; TIV, total intracranial volume.

(2017), with TD participants as a separate group (Figure S4, Table S8). Significant group differences were found between the high CU group, the low CU group, and the TD group. Especially, the high CU group (>30) showed lower GMV in the ACC/MCC, vmPFC and PCu, and additionally, in the amygdala, hippocampus, and insula than the TD group.

## DISCUSSION

The aim of this study was to improve our understanding of the shared and disorder-specific deficits in AE and CE in youth with CD and ASD, as well as the underlying differences in brain structure. We furthermore explored the influence of co-occurring CU traits in these associations across all participants. Overall, our findings do not support a double dissociation of empathy deficits in youth with ASD and CD (Blair, 2013; Blair et al., 2014; Gillespie-Lynch et al., 2017; Igoumenou et al., 2017; Lombardo et al., 2016; Rogers et al., 2007; Schwenck et al., 2012; Shalev et al., 2022; Smith, 2006, 2009), but global empathy deficits for ASD in the parent-report and CE deficits in the self-report, and for CD, parent-reported CE deficits. Interestingly, when CU traits were included in the models, the observed influence of CU traits on empathy aspects was dependent on the disorder. Thus, compared with the TD group, the ASD group no longer showed AE deficits, while the CD group showed no longer CE deficits. Additionally, CU traits were negatively associated with GMV in left ACC extending into MCC and vmPFC, and PCu across all participants.

The potentially overlapping empathy deficits displayed by the group of youths with ASD and those with CD results would be in line with the overlapping aggressive, antisocial, and disruptive symptoms observed in ASD and CD, which were also associated with empathy deficits in previous studies (Frick et al., 2013; Kaat & Lecavalier, 2013). For the ASD group, global empathy deficits were observed, in line with the existing evidence of deficits in CE (K. Rogers et al., 2007; Schwenck et al., 2012; Vilas et al., 2021), but also in abilities that need both AE and CE (Lombardo et al., 2010) such as self-other distinction. Against expectations, CD youths only showed CE deficits in the parent-report and no deficits in the self-report, which might suggest differences between self-perceived and externally observed empathy abilities. Notably, a significant proportion of the parent-reports for CD youths was completed by the main caregivers from institutionalized settings. While the results are comparable to those from previous studies (Waller, Wagner, et al., 2020), it is conceivable that temporary caregivers might have a limited insight into each empathy aspect capacity of the respective adolescent.

Our results indicate that parent-reported CE deficits might be related to CU traits in CD youth but not in those with ASD, in line with previous studies (Waller, Wagner, et al., 2020), and with the potential disorder-specific character of CE deficits in ASD, which would remain significant beyond the presence of CU traits (Jones et al., 2010; Pijper et al., 2016). CU traits have been associated with affective TOM, linked with CE and AE processes (Gao et al., 2019) and might thus be related to AE and the interplay of AE and CE processes, but not CE processes per se. In our study, the inclusion of CU traits in the computational models reduced the relevance of the AE but not CE deficits for the ASD group, suggestive of a potential differential impact of CU traits on empathy deficits on each disorder. These findings would help to understand those of previous studies where deficits in pure CE processes were found only in ASD samples and not in youth with high levels of CU traits (Jones et al., 2010; O'Nions et al., 2014; Schwenck et al., 2012; Vilas et al., 2021). This might further suggest that CE empathy deficits are influenced by other factors in youth with ASD than CD. Thus, CE deficits in ASD youth might be less influenced by CU traits in the social impairment of the disorder than in CD.

Structural brain imaging analyses did not reveal any regions significantly associated with potential differences in empathy aspects, groups, or their interaction. Thus, our results differ from previous evidence suggesting that AE/CE deficits are linked with distinct brain regions in CD and ASD youths (Banissy et al., 2012; Eres et al., 2015; Hoffmann et al., 2016; Klapwijk et al., 2016; O'Nions et al., 2014; von Polier et al., 2020). A key difference with previous brain imaging studies is the use of scores of empathy as trait and measures of brain structure, relative to the commonly used state-like measures of empathy and brain functional measures (Lamm et al., 2011; Moore et al., 2015). Negative associations were however observed between CU traits and GMV in the ACC/MCC, vmPFC, and PCu for both self- and parent-reported empathy across all participants. Atypical brain function and connectivity in these regions have been previously associated with high levels of CU traits (Finger et al., 2008; Marsh, 2018; Marsh et al., 2008; Waller, Wagner, et al., 2020), CD (Sterzer et al., 2005) and psychopathy (Blair et al., 2014; Cheng et al., 2012; de Vignemont & Singer, 2006; Kiehl et al., 2001; Lockwood et al., 2013; Marsh, 2018; Marsh et al., 2013; Rilling et al., 2007; Sterzer et al., 2005). These regions have also been linked to CE (vmPFC), affective TOM (vmPFC) (Sebastian et al., 2012), AE processes (ACC/MCC) (Bernhardt & Singer, 2012; Bzdok et al., 2012; Lamm et al., 2011) and CE processes (Bray et al., 2022; Bzdok et al., 2012; Molenberghs et al., 2016; Schurz et al., 2014; Van Overwalle & Baetens, 2009).

Previous studies investigating the associations between CU traits and brain regions involved in empathy processes have mainly focused on CD populations. Therefore, the relationship between CU traits and ASD remains speculative. However, in ASD patients, functional abnormalities in regions overlapping those that in our sample were related to CU traits have been linked to ASD symptomatology, with dysfunction in the vmPFC linked to self-other distinction processes (Simantov et al., 2021), whereas the ACC and MCC have been linked to affective functioning (Klöbl et al., 2022) and repetitive behaviors (Thakkar et al., 2008). Furthermore, the ACC/MCC and vmPFC are part of the default mode network (DMN) (Menon & Uddin, 2010) whose integrity has been associated with social cognition (Mars et al., 2012; Meyer et al., 2012; Schilbach et al., 2008), empathy processes (Oliveira-Silva et al., 2023), prosocial personality traits (Coutinho et al., 2013; Sampaio et al., 2014) and CE (Winters et al., 2021). The DMN has consistently been shown to be disrupted in ASD patients (Chen et al., 2016; Glerean et al., 2016; Lynch et al., 2013; Mason et al., 2008; Moseley et al., 2015; Nielsen et al., 2013; Yerys et al., 2015; Ypma et al., 2016). Thus, structural abnormalities in vmPFC and ACC/MCC and associated with CU traits might significantly contribute to symptoms of ASD, impairing social cognition and potentially exacerbating their empathy deficits.

Our supplemental analysis revealed structural differences in amygdala, insula and hippocampus in patients with CU trait scores above the clinical cutoff (Docherty et al., 2017) (Figure S4, Table S8). This is in support of previous findings linking these brain regions to the presence of high CU traits (Ibrahim et al., 2019; Waller, Hawes, et al., 2020). These regions have been either linked to AE or global empathy (Bray et al., 2022; Cardinale et al., 2019; Fan et al., 2011; Goerlich-Dobre et al., 2015; Lozier et al., 2014; Marsh et al., 2013; Stern et al., 2019) and with the amygdala being a hub for overall emotion-related processing (Gothard, 2020; Šimić et al., 2021) it is conceivable that CU traits might also represent a transdiagnostic indicator for emotion processing deficits. The presence of CU traits might therefore play an important role in a range of emotion-related processes such as empathy, with deficits displayed not only in patients with CD but also in other psychiatric disorders (Kraiss et al., 2020; Kret & Ploeger, 2015; McTeague et al., 2020).

In ASD and TD groups, self- and parent-reports showed low correlations in AE and no correlations in CE. Furthermore, no correlations in CE or AE were observed between self- and parent-reports in the CD group implying that these reports could measure different concepts of empathy. Notably, there is still a lack of consensus on the definition of the concept of empathy (Coplan, 2011; de Vignemont & Singer, 2006; Eklund & Meranius, 2021; Engelen & Röttger-Rössler, 2012). This highlights the key role of the questionnaire used, and the potential need to collect both self- and parent-reported measures in young clinical populations with ASD and CD.

This study has potential limitations. For the ASD group, only adolescents with high functioning autism or Asperger's syndrome were recruited, to overcome possible language and cognitive barriers (Betancur, 2011) which necessarily limits the generalizability of our findings to a subgroup within this heterogeneous disorder. Previous findings revealed no differences in social skills between ASD youth with and without intellectual disabilities (Baker & Blacher, 2020) however, whether there are empathy differences needs to be further investigated. Furthermore, although we included female and male participants in our study, the large majority of participants in both patient groups are males. While potentially reflecting the higher prevalence rate among males in both disorders (Loomes et al., 2017; Merikangas et al., 2010), sex differences have been described in both disorders (Fairchild et al., 2013; Ibrahim et al., 2021; Lai & Szatmari, 2020; Napolitano et al., 2022; Ypma et al., 2016). Our supplementary results are also indicative of a potential impact of sex on self-reported AE, however, given the low numbers of females in the patient groups, results remain preliminary. Hence, future studies should explore potential sex-specific differences in empathy capacities in samples with a more balanced female-to-male ratio. An additional aspect to consider is the presence of comorbidities, especially Attention Deficit Hyperactivity Disorder (ADHD), a common comorbid diagnosis in ASD and CD youth (Antshel & Russo, 2019; Fairchild et al., 2019). The presence of both ADHD and CU traits in neurodevelopmental disorders is common (Squillaci & Benoit, 2021). Although CU traits have been discussed as a cross-disorder indicator for empathy deficits, these might also overlap with empathy deficits described in ADHD (Braaten & Rosén, 2000; Maoz et al., 2019; Parke et al., 2021). Thus, investigating the potential influence of both CU traits and ADHD symptomatology in these disorders might help to dissect disorder-specific empathy deficits associated with CU traits and/or ADHD. Finally, larger sample sizes would be needed. Model comparison results show low standard errors implying that larger sample sizes are needed to confidently confirm a potentially better model fit with CU traits included in the model.

To sum up, our results do not support the presence of a double dissociation in AE and CE deficits in youths with ASD or CD. However, CE deficits in CD adolescents were closely related to the presence of CU traits whereas in youths with ASD this association was only observed for AE deficits. Our findings however, confirm the association between CU traits and global empathy deficits (Jones et al., 2010; Waller et al., 2015). This also highlights CU traits as being a potentially transdiagnostic indicator for empathy and possibly overall emotion processing deficits, which extends previous findings linking symptomatic overlaps between ASD and CD youth with CU traits (Carter Leno et al., 2015; Frick et al., 2013; Herpers et al., 2016; Kaat & Lecavalier, 2013; Pasalich et al., 2014). The lack of a significant association between CU traits and CE deficits in the ASD group might be suggestive of disorder-specific empathy deficits going beyond the influence of CU traits. Thus, specific CE deficits might represent a core impairment in ASD which could be specifically targeted by interventions to improve empathy skills in this disorder. Given the discrepancy in the measures of empathy, future studies might consider the combination of self-and parent-reports and task-based empathy measures to detect specific AE/CE deficits associated with ASD and CD psychopathologies.

## ACKNOWLEDGMENTS

We thank all adolescents, families, institutions, and professionals who participated in the study. This study and AT were supported by the Swiss National Science Foundation (Grant no. 100014_185408/1). Open access funding provided by Universitat Basel.

## CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflicts of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## ETHICS STATEMENT

All procedures were conducted in accordance with the Declaration of Helsinki and approved by the local Ethics Committee (EKNZ, 2019-02386).

## ORCID

*Antonia Tkalcec* https://orcid.org/0000-0003-2872-5882
*Evelyn Herbrecht* https://orcid.org/0000-0003-3287-6261

## REFERENCES

American Psychiatric Association, DSM-5 Task Force. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5™* (5th ed.). American Psychiatric Publishing Inc.

Angold, A., Costello, E. J., & Erkanli, A. (1999). Comorbidity. *Journal of Child Psychology and Psychiatry*, *40*(1), 57–87. https://doi.org/10.1111/1469-7610.00424

Antshel, K. M., & Russo, N. (2019). Autism Spectrum disorders and ADHD: Overlapping phenomenology, diagnostic issues, and treatment considerations. *Current Psychiatry Reports*, *21*(5), 34. https://doi.org/10.1007/s11920-019-1020-5

Ashburner, J., & Friston, K. J. (2000). Voxel-based morphometry—The methods. *NeuroImage*, *11*(6), 805–821. https://doi.org/10.1006/nimg.2000.0582

Baker, B. L., & Blacher, J. (2020). Brief report: Behavior disorders and social skills in adolescents with autism Spectrum disorder: Does IQ matter? *Journal of Autism and Developmental Disorders*, *50*(6), 2226–2233. https://doi.org/10.1007/s10803-019-03954-w

Banissy, M. J., Kanai, R., Walsh, V., & Rees, G. (2012). Inter-individual differences in empathy are reflected in human brain structure. *NeuroImage*, *62*(3), 2034–2039. https://doi.org/10.1016/j.neuroimage.2012.05.081

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition*, *21*(1), 37–46. https://doi.org/10.1016/0010-0277(85)90022-8

Baron-Cohen, S., & Wheelwright, S. (2004). The empathy quotient: An investigation of adults with Asperger syndrome or high functioning autism, and Normal sex differences. *Journal of Autism and Developmental Disorders*, *34*(2), 163–175. https://doi.org/10.1023/B:JADD.0000022607.19833.00

Bernhardt, B. C., & Singer, T. (2012). The neural basis of empathy. *Annual Review of Neuroscience*, *35*(1), 1–23. https://doi.org/10.1146/annurev-neuro-062111-150536

Betancur, C. (2011). Etiological heterogeneity in autism spectrum disorders: More than 100 genetic and genomic disorders and still counting. *Brain Research*, *1380*, 42–77. https://doi.org/10.1016/j.brainres.2010.11.078

Blair, J. (2005). Responding to the emotions of others: Dissociating forms of empathy through the study of typical and psychiatric populations. *Consciousness and Cognition*, *14*(4), 698–718. https://doi.org/10.1016/j.concog.2005.06.004

Blair, J. (2013). The neurobiology of psychopathic traits in youths. *Nature Reviews Neuroscience*, *14*(11), 786–799. https://doi.org/10.1038/nrn3577

Blair, J., Leibenluft, E., & Pine, D. S. (2014). Conduct disorder and callous–unemotional traits in youth. *New England Journal of*

Medicine, 371(23), 2207–2216. https://doi.org/10.1056/NEJMra1315612

Blakemore, S.-J. (2012). Development of the social brain in adolescence. *Journal of the Royal Society of Medicine*, *105*(3), 111–116. https://doi.org/10.1258/jrsm.2011.110221

Bölte, S., Rühl, D., Schmötzer, G., & Poustka, F. (2006). *ADI-R*. Diagnostisches Interview Für Autismus-Revidiert.

Braaten, E. B., & Rosén, L. A. (2000). Self-regulation of affect in attention deficit-hyperactivity disorder (ADHD) and non-ADHD boys: Differences in empathic responding. *Journal of Consulting and Clinical Psychology*, *68*(2), 313–321. https://doi.org/10.1037/0022-006X.68.2.313

Bray, K. O., Pozzi, E., Vijayakumar, N., Richmond, S., Deane, C., Pantelis, C., Anderson, V., & Whittle, S. (2022). Individual differences in brain structure and self-reported empathy in children. *Cognitive, Affective, & Behavioral Neuroscience*, *22*(5), 1078–1089. https://doi.org/10.3758/s13415-022-00993-2

Brett, M., Anton, J. L., Valabrgue, R., & Poline, J.-B. (2002). Region of interest analysis using an SPM toolbox. *Presented at the 8th International Conference on Functional Mapping of the Human Brain*, June 2-6, 2002, Neuroimage, 13, 210–217.

Burghart, M., & Mier, D. (2022). No feelings for me, no feelings for you: A meta-analysis on alexithymia and empathy in psychopathy. *Personality and Individual Differences*, *194*, 111658. https://doi.org/10.1016/j.paid.2022.111658

Bzdok, D., Schilbach, L., Vogeley, K., Schneider, K., Laird, A. R., Langner, R., & Eickhoff, S. B. (2012). Parsing the neural correlates of moral cognition: ALE meta-analysis on morality, theory of mind, and empathy. *Brain Structure and Function*, *217*(4), 783–796. https://doi.org/10.1007/s00429-012-0380-y

Campos, C., Pasion, R., Azeredo, A., Ramião, E., Mazer, P., Macedo, I., & Barbosa, F. (2022). Refining the link between psychopathy, antisocial behavior, and empathy: A meta-analytical approach across different conceptual frameworks. *Clinical Psychology Review*, *94*, 102145. https://doi.org/10.1016/j.cpr.2022.102145

Cantio, C., Jepsen, J. R. M., Madsen, G. F., Bilenberg, N., & White, S. J. (2016). Exploring 'the autisms' at a cognitive level: Exploring 'the autisms' at a cognitive level. *Autism Research*, *9*(12), 1328–1339. https://doi.org/10.1002/aur.1630

Cardinale, E. M., O'Connell, K., Robertson, E. L., Meena, L. B., Breeden, A. L., Lozier, L. M., VanMeter, J. W., & Marsh, A. A. (2019). Callous and uncaring traits are associated with reductions in amygdala volume among youths with varying levels of conduct problems. *Psychological Medicine*, *49*(9), 1449–1458. https://doi.org/10.1017/S0033291718001927

Carter Leno, V., Bedford, R., Chandler, S., White, P., Yorke, I., Charman, T., Pickles, A., & Simonoff, E. (2021). Callous-unemotional traits in youth with autism spectrum disorder (ASD): Replication of prevalence estimates and associations with gaze patterns when viewing fearful faces. *Development and Psychopathology*, *33*(4), 1220–1228. https://doi.org/10.1017/S0954579420000449

Carter Leno, V., Charman, T., Pickles, A., Jones, C. R. G., Baird, G., Happé, F., & Simonoff, E. (2015). Callous-unemotional traits in adolescents with autism spectrum disorder. *The British Journal of Psychiatry: the Journal of Mental Science*, *207*(5), 392–399. https://doi.org/10.1192/bjp.bp.114.159863

Chen, H., Duan, X., Liu, F., Lu, F., Ma, X., Zhang, Y., Uddin, L. Q., & Chen, H. (2016). Multivariate classification of autism spectrum disorder using frequency-specific resting-state functional connectivity—A multi-center study. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *64*, 1–9. https://doi.org/10.1016/j.pnpbp.2015.06.014

Cheng, Y., Hung, A.-Y., & Decety, J. (2012). Dissociation between affective sharing and emotion understanding in juvenile psychopaths. *Development and Psychopathology*, *24*(2), 623–636. https://doi.org/10.1017/S095457941200020X

Coplan, A. (2011). Will the real empathy please stand up? A CASE for a narrow conceptualization: Will the real empathy please stand up? *The Southern Journal of Philosophy*, *49*, 40–65. https://doi.org/10.1111/j.2041-6962.2011.00056.x

Coutinho, J. F., Sampaio, A., Ferreira, M., Soares, J. M., & Gonçalves, O. F. (2013). Brain correlates of pro-social personality traits: A voxel-based morphometry study. *Brain Imaging and Behavior*, *7*(3), 293–299. https://doi.org/10.1007/s11682-013-9227-2

Dadds, M. R., Hunter, K., Hawes, D. J., Frost, A. D. J., Vassallo, S., Bunn, P., Merz, S., & Masry, Y. E. (2008). A measure of cognitive and affective empathy in children using parent ratings. *Child Psychiatry and Human Development*, *39*(2), 111–122. https://doi.org/10.1007/s10578-007-0075-4

de Vignemont, F., & Singer, T. (2006). The empathic brain: How, when and why? *Trends in Cognitive Sciences*, *10*(10), 435–441. https://doi.org/10.1016/j.tics.2006.08.008

de Waal, F. B. M., & Preston, S. D. (2017). Mammalian empathy: Behavioural manifestations and neural basis. *Nature Reviews Neuroscience*, *18*(8), 498–509. https://doi.org/10.1038/nrn.2017.72

Decety, J., & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews*, *3*(2), 71–100. https://doi.org/10.1177/1534582304267187

Del Casale, A., Ferracuti, S., Alcibiade, A., Simone, S., Modesti, M. N., & Pompili, M. (2022). Neuroanatomical correlates of autism spectrum disorders: A meta-analysis of structural magnetic resonance imaging (MRI) studies. *Psychiatry Research: Neuroimaging*, *325*, 111516. https://doi.org/10.1016/j.pscychresns.2022.111516

Di Martino, A., Fair, D. A., Kelly, C., Satterthwaite, T. D., Castellanos, F. X., Thomason, M. E., Craddock, R. C., Luna, B., Leventhal, B. L., Zuo, X.-N., & Milham, M. P. (2014). Unraveling the Miswired connectome: A developmental perspective. *Neuron*, *83*(6), 1335–1353. https://doi.org/10.1016/j.neuron.2014.08.050

Docherty, M., Boxer, P., Huesmann, L. R., O'Brien, M., & Bushman, B. (2017). Assessing callous-unemotional traits in adolescents: Determining cutoff scores for the inventory of callous and unemotional traits: Determining the cutoff for the ICU. *Journal of Clinical Psychology*, *73*(3), 257–278. https://doi.org/10.1002/jclp.22313

Dumontheil, I. (2016). Adolescent brain development. *Current Opinion in Behavioral Sciences*, *10*, 39–44. https://doi.org/10.1016/j.cobeha.2016.04.012

Dvash, J., & Shamay-Tsoory, S. G. (2014). Theory of mind and empathy as multidimensional constructs: Neurological foundations. *Topics in Language Disorders*, *34*(4), 282–295. https://doi.org/10.1097/TLD.0000000000000040

Eisenberg, N. (2010). Empathy-related responding: Links with self-regulation, moral judgment, and moral behavior. In M. Mikulincer & P. R. Shaver (Eds.), *Prosocial motives, emotions, and behavior: The better angels of our nature* (pp. 129–148). American Psychological Association. https://doi.org/10.1037/12061-007

Eisenberg, N., Shea, C. L., Carlo, G., & Knight, G. P. (2014). Empathy-related responding and cognition: A "chicken and the egg" dilemma. In *Handbook of moral behavior and development* (pp. 85–110). Psychology Press. https://doi.org/10.4324/9781315807287-11

Eklund, J. H., & Meranius, M. S. (2021). Toward a consensus on the nature of empathy: A review of reviews. *Patient Education and Counseling*, *104*(2), 300–307.

Engelen, E.-M., & Röttger-Rössler, B. (2012). Current disciplinary and interdisciplinary debates on empathy. *Emotion Review*, *4*(1), 3–8. https://doi.org/10.1177/1754073911422287

Eres, R., Decety, J., Louis, W. R., & Molenberghs, P. (2015). Individual differences in local gray matter density are associated with differences in affective and cognitive empathy. *NeuroImage*, *117*, 305–310. https://doi.org/10.1016/j.neuroimage.2015.05.038

Erskine, H. E., Ferrari, A. J., Polanczyk, G. V., Moffitt, T. E., Murray, C. J. L., Vos, T., Whiteford, H. A., & Scott, J. G. (2014). The global burden of conduct disorder and attention-deficit/hyperactivity disorder in 2010. *Journal of Child Psychology and Psychiatry*, *55*(4), 328–336. https://doi.org/10.1111/jcpp.12186

Erskine, H. E., Norman, R. E., Ferrari, A. J., Chan, G. C. K., Copeland, W. E., Whiteford, H. A., & Scott, J. G. (2016). Long-term outcomes of attention-deficit/hyperactivity disorder and conduct disorder: A systematic review and meta-analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, *55*(10), 841–850. https://doi.org/10.1016/j.jaac.2016.06.016

Fairchild, G., Hagan, C. C., Walsh, N. D., Passamonti, L., Calder, A. J., & Goodyer, I. M. (2013). Brain structure abnormalities in adolescent girls with conduct disorder. *Journal of Child Psychology and Psychiatry*, *54*(1), 86–95. https://doi.org/10.1111/j.1469-7610.2012.02617.x

Fairchild, G., Hawes, D. J., Frick, P. J., Copeland, W. E., Odgers, C. L., Franke, B., Freitag, C. M., & De Brito, S. A. (2019). Conduct disorder. *Nature Reviews. Disease Primers*, *5*(1), 43. https://doi.org/10.1038/s41572-019-0095-y

Fan, Y., Duncan, N. W., de Greck, M., & Northoff, G. (2011). Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. *Neuroscience & Biobehavioral Reviews*, *35*(3), 903–911. https://doi.org/10.1016/j.neubiorev.2010.10.009

Finger, E. C., Marsh, A. A., Mitchell, D. G., Reid, M. E., Sims, C., Budhani, S., Kosson, D. S., Chen, G., Towbin, K. E., Leibenluft, E., Pine, D. S., & Blair, J. R. (2008). Abnormal ventromedial prefrontal cortex function in children with psychopathic traits during reversal learning. *Archives of General Psychiatry*, *65*(5), 586–594. https://doi.org/10.1001/archpsyc.65.5.586

Fontaine, N. M. G., McCrory, E. J. P., Boivin, M., Moffitt, T. E., & Viding, E. (2011). Predictors and outcomes of joint trajectories of callous–unemotional traits and conduct problems in childhood. *Journal of Abnormal Psychology*, *120*(3), 730–742. https://doi.org/10.1037/a0022620

Foster, E. M., Jones, D. E., & and The Conduct Problems Prevention Research Group. (2005). The high costs of aggression: Public expenditures resulting from conduct disorder. *American Journal of Public Health*, *95*(10), 1767–1772. https://doi.org/10.2105/AJPH.2004.061424

Frick, P. J. (2017). *Inventory of callous–unemotional traits [Data set]*. American Psychological Association. https://doi.org/10.1037/t62639-000

Frick, P. J., Blair, R. J., & Castellanos, F. X. (2013). Callous-unemotional traits and developmental pathways to the disruptive behavior disorders. In P. H. Tolan & B. L. Leventhal (Eds.), *Disruptive behavior disorders* (pp. 69–102). Springer. https://doi.org/10.1007/978-1-4614-7557-6_4

Frick, P. J., Cornell, A. H., Bodin, S. D., Dane, H. E., Barry, C. T., & Loney, B. R. (2003). Callous-unemotional traits and developmental pathways to severe conduct problems. *Developmental Psychology*, *39*(2), 246–260. https://doi.org/10.1037/0012-1649.39.2.246

Frick, P. J., & Kemp, E. C. (2021). Conduct disorders and empathy development. *Annual Review of Clinical Psychology*, *17*(1), 391–416. https://doi.org/10.1146/annurev-clinpsy-081219-105809

Frick, P. J., & Nigg, J. T. (2012). Current issues in the diagnosis of attention deficit hyperactivity disorder, oppositional defiant disorder, and conduct disorder. *Annual Review of Clinical Psychology*, *8*(1), 77–107. https://doi.org/10.1146/annurev-clinpsy-032511-143150

Frith, U. (2001). Mind blindness and the brain in autism. *Neuron*, *32*(6), 969–979. https://doi.org/10.1016/S0896-6273(01)00552-9

Frith, U., & Frith, C. D. (2003). Development and neurophysiology of mentalizing. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *358*(1431), 459–473. https://doi.org/10.1098/rstb.2002.1218

Fuhrmann, D., Knoll, L. J., & Blakemore, S.-J. (2015). Adolescence as a sensitive period of brain development. *Trends in Cognitive Sciences*, *19*(10), 558–566. https://doi.org/10.1016/j.tics.2015.07.008

Gao, Y., Rogers, J. C., Pauli, R., Clanton, R., Baker, R., Birch, P., Ferreira, L., Brown, A., Freitag, C. M., Fairchild, G., Rotshtein, P., & De Brito, S. A. (2019). Neural correlates of theory of mind in typically-developing youth: Influence of sex, age and callous-unemotional traits. *Scientific Reports*, *9*(1), 16216. https://doi.org/10.1038/s41598-019-52261-y

Gaser, C., & Dahnke, R. (2016). CAT - a computational anatomy toolbox for the analysis of structural MRI data. HBM. http://www.neuro.unijena.de/hbm2016/GaserHBM2016.pdf

Georgiou, G., Kimonis, E. R., & Fanti, K. A. (2019). What do others feel? Cognitive empathy deficits explain the association between callous-unemotional traits and conduct problems among preschool children. *European Journal of Developmental Psychology*, *16*(6), 633–653. https://doi.org/10.1080/17405629.2018.1478810

Gillespie-Lynch, K., Kapp, S. K., Brooks, P. J., Pickens, J., & Schwartzman, B. (2017). Whose expertise is it? Evidence for autistic adults as critical autism experts. *Frontiers in Psychology*, *8*, pp. 1–14. https://doi.org/10.3389/fpsyg.2017.00438

Glerean, E., Pan, R. K., Salmi, J., Kujala, R., Lahnakoski, J. M., Roine, U., Nummenmaa, L., Leppämäki, S., Nieminen-von Wendt, T., Tani, P., Saramäki, J., Sams, M., & Jääskeläinen, I. P. (2016). Reorganization of functionally connected brain subnetworks in high-functioning autism. *Human Brain Mapping*, *37*(3), 1066–1079. https://doi.org/10.1002/hbm.23084

Goerlich-Dobre, K. S., Lamm, C., Pripfl, J., Habel, U., & Votinov, M. (2015). The left amygdala: A shared substrate of alexithymia and empathy. *NeuroImage*, *122*, 20–32. https://doi.org/10.1016/j.neuroimage.2015.08.014

Gothard, K. M. (2020). Multidimensional processing in the amygdala. *Nature Reviews Neuroscience*, *21*(10), 565–575. https://doi.org/10.1038/s41583-020-0350-y

Grove, R., Baillie, A., Allison, C., Baron-Cohen, S., & Hoekstra, R. A. (2014). The latent structure of cognitive and emotional empathy in individuals with autism, first-degree relatives and typical individuals. *Molecular Autism*, *5*(1), 42. https://doi.org/10.1186/2040-2392-5-42

Happé, F., Cook, J. L., & Bird, G. (2017). The structure of social cognition: In(ter)dependence of Sociocognitive processes. *Annual Review of Psychology*, *68*(1), 243–267. https://doi.org/10.1146/annurev-psych-010416-044046

Herpers, P. C. M., Klip, H., Rommelse, N. N. J., Greven, C. U., & Buitelaar, J. K. (2016). Associations between high callous–unemotional traits and quality of life across youths with non-conduct disorder diagnoses. *European Child & Adolescent Psychiatry*, *25*(5), 547–555. https://doi.org/10.1007/s00787-015-0766-5

Hoffmann, F., Koehne, S., Steinbeis, N., Dziobek, I., & Singer, T. (2016). Preserved self-other distinction during empathy in autism is linked to network integrity of right supramarginal gyrus. *Journal of Autism and Developmental Disorders*, *46*(2), 637–648. https://doi.org/10.1007/s10803-015-2609-0

Hyde, L. W., & Dotterer, H. L. (2022). The nature and nurture of callous-unemotional traits. *Current Directions in Psychological Science*, *31*(6), 546–555. https://doi.org/10.1177/09637214221121302

Ibrahim, K., Eilbott, J. A., Ventola, P., He, G., Pelphrey, K. A., McCarthy, G., & Sukhodolsky, D. G. (2019). Reduced amygdala–prefrontal functional connectivity in children with autism Spectrum disorder and Co-occurring disruptive behavior. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *4*(12), 1031–1041. https://doi.org/10.1016/j.bpsc.2019.01.009

Ibrahim, K., Kalvin, C., Li, F., He, G., Pelphrey, K. A., McCarthy, G., & Sukhodolsky, D. G. (2021). Sex differences in medial prefrontal and parietal cortex structure in children with disruptive behavior. *Developmental Cognitive Neuroscience*, *47*, 100884. https://doi.org/10.1016/j.dcn.2020.100884

Igoumenou, A., Harmer, C. J., Yang, M., Coid, J. W., & Rogers, R. D. (2017). Faces and facets: The variability of emotion recognition in psychopathy reflects its affective and antisocial features. *Journal of Abnormal Psychology*, *126*(8), 1066–1076. https://doi.org/10.1037/abn0000293

Jolliffe, D., & Farrington, D. P. (2006). Development and validation of the basic empathy scale. *Journal of Adolescence*, *29*(4), 589–611. https://doi.org/10.1016/j.adolescence.2005.08.010

Jones, A. P., Happé, F. G. E., Gilbert, F., Burnett, S., & Viding, E. (2010). Feeling, caring, knowing: Different types of empathy deficit in boys with psychopathic tendencies and autism spectrum disorder. *Journal of Child Psychology and Psychiatry*, *51*(11), 1188–1197. https://doi.org/10.1111/j.1469-7610.2010.02280.x

Kaat, A. J., & Lecavalier, L. (2013). Disruptive behavior disorders in children and adolescents with autism spectrum disorders: A review of the prevalence, presentation, and treatment. *Research in Autism Spectrum Disorders*, *7*(12), 1579–1594. https://doi.org/10.1016/j.rasd.2013.08.012

Kaufmann, J., Birnahrer, B., Brent, D., Rao, U., Flynn, C., Moreci, P., Williamson, D., & Ryan, N. (1997). Schedule for affective disorders and schizophrenia for school-age children-present and lifetime version (K-SADS-PL). *Initial Reliability and Validity Data*, *36*(7), 980–988. https://doi.org/10.1097/00004583-199707000-00021

Kiehl, K. A., Smith, A. M., Hare, R. D., Mendrek, A., Forster, B. B., Brink, J., & Liddle, P. F. (2001). Limbic abnormalities in affective processing by criminal psychopaths as revealed by functional magnetic resonance imaging. *Biological Psychiatry*, *50*(9), 677–684. https://doi.org/10.1016/S0006-3223(01)01222-7

Kim, E. J., Son, J.-W., Park, S. K., Chung, S., Ghim, H.-R., Lee, S., Lee, S.-I., Shin, C.-J., Kim, S., Ju, G., Park, H., & Lee, J. (2020). Cognitive and emotional empathy in young adolescents: An fMRI study. *Journal of the Korean Academy of Child and Adolescent Psychiatry*, *31*(3), 121–130. https://doi.org/10.5765/jkacap.200020

Klapwijk, E. T., Aghajani, M., Colins, O. F., Marijnissen, G. M., Popma, A., Lang, N. D. J., Wee, N. J. A., & Vermeiren, R. R. J. M. (2016). Different brain responses during empathy in autism spectrum disorders versus conduct disorder and callous-unemotional traits. *Journal of Child Psychology and Psychiatry*, *57*(6), 737–747. https://doi.org/10.1111/jcpp.12498

Klöbl, M., Prillinger, K., Diehm, R., Doganay, K., Lanzenberger, R., Poustka, L., Plener, P., & Konicar, L. (2022). Individual brain regulation as learned via neurofeedback is related to affective changes in adolescents with autism spectrum disorder. *Child and Adolescent Psychiatry and Mental Health*, *17*(1), 1–14.

Kraiss, J. T., Ten Klooster, P. M., Moskowitz, J. T., & Bohlmeijer, E. T. (2020). The relationship between emotion regulation and well-being in patients with mental disorders: A meta-analysis. *Comprehensive Psychiatry*, *102*, 152189. https://doi.org/10.1016/j.comppsych.2020.152189

Kret, M. E., & Ploeger, A. (2015). Emotion processing deficits: A liability spectrum providing insight into comorbidity of mental disorders. *Neuroscience & Biobehavioral Reviews*, *52*, 153–171. https://doi.org/10.1016/j.neubiorev.2015.02.011

Lai, M.-C., & Szatmari, P. (2020). Sex and gender impacts on the behavioural presentation and recognition of autism. *Current Opinion in Psychiatry*, *33*(2), 117–123. https://doi.org/10.1097/YCO.0000000000000575

Lamm, C., Decety, J., & Singer, T. (2011). Meta-analytic evidence for common and distinct neural networks associated with directly experienced pain and empathy for pain. *NeuroImage*, *54*(3), 2492–2502. https://doi.org/10.1016/j.neuroimage.2010.10.014

Lawing, K., Frick, P. J., & Cruise, K. R. (2010). Differences in offending patterns between adolescent sex offenders high or low in callous—Unemotional traits. *Psychological Assessment*, *22*(2), 298–305. https://doi.org/10.1037/a0018707

Lockwood, P. L., Sebastian, C. L., McCrory, E. J., Hyde, Z. H., Gu, X., De Brito, S. A., & Viding, E. (2013). Association of Callous Traits with reduced neural response to Others' pain in children with conduct problems. *Current Biology*, *23*(10), 901–905. https://doi.org/10.1016/j.cub.2013.04.018

Loeber, R., Burke, J. D., & Pardini, D. A. (2009). Development and etiology of disruptive and delinquent behavior. *Annual Review of Clinical Psychology*, *5*(1), 291–310. https://doi.org/10.1146/annurev.clinpsy.032408.153631

Lombardo, M. V., Chakrabarti, B., Bullmore, E. T., Sadek, S. A., Pasco, G., Wheelwright, S. J., Suckling, J., MRC AIMS Consortium, & Baron-Cohen, S. (2010). Atypical neural self-representation in autism. Brain: A. *Journal of Neurology*, *133*(Pt 2), 611–624. https://doi.org/10.1093/brain/awp306

Lombardo, M. V., Lai, M.-C., Auyeung, B., Holt, R. J., Allison, C., Smith, P., Chakrabarti, B., Ruigrok, A. N. V., Suckling, J., Bullmore, E. T., Consortium, M. R. C. A. I. M. S., Bailey, A. J., Baron-Cohen, S., Bolton, P. F., Bullmore, E. T., Carrington, S., Catani, M., Chakrabarti, B., Craig, M. C., … Baron-Cohen, S. (2016). Unsupervised data-driven stratification of mentalizing heterogeneity in autism. *Scientific Reports*, *6*(1), 35333. https://doi.org/10.1038/srep35333

Loomes, R., Hull, L., & Mandy, W. P. L. (2017). What is the male-to-female ratio in autism Spectrum disorder? A systematic review and meta-analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, *56*(6), 466–474. https://doi.org/10.1016/j.jaac.2017.03.013

Lozier, L. M., Cardinale, E. M., VanMeter, J. W., & Marsh, A. A. (2014). Mediation of the relationship between callous-unemotional traits and proactive aggression by amygdala response to fear among children with conduct problems. *JAMA Psychiatry*, *71*(6), 627–636. https://doi.org/10.1001/jamapsychiatry.2013.4540

Lynch, C. J., Uddin, L. Q., Supekar, K., Khouzam, A., Phillips, J., & Menon, V. (2013). Default mode network in childhood autism: Posteromedial cortex heterogeneity and relationship with social deficits. *Biological Psychiatry*, *74*(3), 212–219. https://doi.org/10.1016/j.biopsych.2012.12.013

Maoz, H., Gvirts, H. Z., Sheffer, M., & Bloch, Y. (2019). Theory of mind and empathy in children with ADHD. *Journal of Attention Disorders*, *23*(11), 1331–1338. https://doi.org/10.1177/1087054717710766

Mars, R. B., Neubert, F.-X., Noonan, M. P., Sallet, J., Toni, I., & Rushworth, M. F. S. (2012). On the relationship between the "default mode network" and the "social brain". *Frontiers in Human Neuroscience*, *6*, pp. 1–9. https://doi.org/10.3389/fnhum.2012.00189

Marsh, A. A. (2018). The neuroscience of empathy. *Current Opinion in Behavioral Sciences*, *19*, 110–115. https://doi.org/10.1016/j.cobeha.2017.12.016

Marsh, A. A., Finger, E. C., Fowler, K. A., Adalio, C. J., Jurkowitz, I. T. N., Schechter, J. C., Pine, D. S., Decety, J., & Blair, R. J. R. (2013). Empathic responsiveness in amygdala and anterior cingulate cortex in youths with psychopathic traits. *Journal of Child Psychology and Psychiatry*, *54*(8), 900–910. https://doi.org/10.1111/jcpp.12063

Marsh, A. A., Finger, E. C., Mitchell, D. G. V., Reid, M. E., Sims, C., Kosson, D. S., Towbin, K. E., Leibenluft, E., Pine, D. S., & Blair, R. J. R. (2008). Reduced amygdala response to fearful expressions in children and adolescents with callous-unemotional traits and disruptive behavior disorders. *American Journal of Psychiatry*, *165*(6), 712–720. https://doi.org/10.1176/appi.ajp.2007.07071145

Martin-Key, N., Brown, T., & Fairchild, G. (2017). Empathic accuracy in male adolescents with conduct disorder and higher versus lower levels of callous-unemotional traits. *Journal of Abnormal Child Psychology*, *45*(7), 1385–1397. https://doi.org/10.1007/s10802-016-0243-8

Mason, R. A., Williams, D. L., Kana, R. K., Minshew, N., & Just, M. A. (2008). Theory of mind disruption and recruitment of the right hemisphere during narrative comprehension in autism. *Neuropsychologia*, *46*(1), 269–280. https://doi.org/10.1016/j.neuropsychologia.2007.07.018

McMahon, R. J., Witkiewitz, K., Kotler, J. S., & The Conduct Problems Prevention Research Group. (2010). Predictive validity of callous–unemotional traits measured in early adolescence with respect to multiple antisocial outcomes. *Journal of Abnormal Psychology*, *119*(4), 752–763. https://doi.org/10.1037/a0020796

McTeague, L. M., Rosenberg, B. M., Lopez, J. W., Carreon, D. M., Huemer, J., Jiang, Y., Chick, C. F., Eickhoff, S. B., & Etkin, A. (2020). Identification of common neural circuit disruptions in emotional processing across psychiatric disorders. *American Journal of Psychiatry*, *177*(5), 411–421. https://doi.org/10.1176/appi.ajp.2019.18111271

Menon, V., & Uddin, L. Q. (2010). Saliency, switching, attention and control: A network model of insula function. *Brain Structure* *and Function*, *214*(5–6), 655–667. https://doi.org/10.1007/s00429-010-0262-0

Merikangas, K. R., He, J., Burstein, M., Swanson, S. A., Avenevoli, S., Cui, L., Benjet, C., Georgiades, K., & Swendsen, J. (2010). Lifetime prevalence of mental disorders in U.S. adolescents: Results from the National Comorbidity Survey Replication–Adolescent Supplement (NCS-A). *Journal of the American Academy of Child & Adolescent Psychiatry*, *49*(10), 980–989. https://doi.org/10.1016/j.jaac.2010.05.017

Meyer, M. L., Spunt, R. P., Berkman, E. T., Taylor, S. E., & Lieberman, M. D. (2012). Evidence for social working memory from a parametric functional MRI study. *Proceedings of the National Academy of Sciences*, *109*(6), 1883–1888. https://doi.org/10.1073/pnas.1121077109

Mills, K. L., Goddings, A.-L., Herting, M. M., Meuwese, R., Blakemore, S.-J., Crone, E. A., Dahl, R. E., Güroğlu, B., Raznahan, A., Sowell, E. R., & Tamnes, C. K. (2016). Structural brain development between childhood and adulthood: Convergence across four longitudinal samples. *NeuroImage*, *141*, 273–281. https://doi.org/10.1016/j.neuroimage.2016.07.044

Molenberghs, P., Johnson, H., Henry, J. D., & Mattingley, J. B. (2016). Understanding the minds of others: A neuroimaging meta-analysis. *Neuroscience & Biobehavioral Reviews*, *65*, 276–291. https://doi.org/10.1016/j.neubiorev.2016.03.020

Moore, R. C., Dev, S. I., Jeste, D. V., Dziobek, I., & Eyler, L. T. (2015). Distinct neural correlates of emotional and cognitive empathy in older adults. *Psychiatry Research: Neuroimaging*, *232*(1), 42–50. https://doi.org/10.1016/j.pscychresns.2014.10.016

Moseley, R. L., Ypma, R. J. F., Holt, R. J., Floris, D., Chura, L. R., Spencer, M. D., Baron-Cohen, S., Suckling, J., Bullmore, E., & Rubinov, M. (2015). Whole-brain functional hypoconnectivity as an endophenotype of autism in adolescents. *NeuroImage: Clinical*, *9*, 140–152. https://doi.org/10.1016/j.nicl.2015.07.015

Mutschler, I., Reinbold, C., Wankerl, J., Seifritz, E., & Ball, T. (2013). Structural basis of empathy and the domain general region in the anterior insular cortex. *Frontiers in Human Neuroscience*, *7*, pp. 1–18. https://doi.org/10.3389/fnhum.2013.00177

Naor, N., Rohr, C., Schaare, L. H., Limbachia, C., Shamay-Tsoory, S., & Okon-Singer, H. (2020). The neural networks underlying reappraisal of empathy for pain. *Social Cognitive and Affective Neuroscience*, *15*(7), 733–744. https://doi.org/10.1093/scan/nsaa094

Napolitano, A., Schiavi, S., La Rosa, P., Rossi-Espagnet, M. C., Petrillo, S., Bottino, F., Tagliente, E., Longo, D., Lupi, E., Casula, L., Valeri, G., Piemonte, F., Trezza, V., & Vicari, S. (2022). Sex differences in autism Spectrum disorder: Diagnostic, neurobiological, and behavioral features. *Frontiers in Psychiatry*, *13*, 889636. https://doi.org/10.3389/fpsyt.2022.889636

Nielsen, J. A., Zielinski, B. A., Fletcher, P. T., Alexander, A. L., Lange, N., Bigler, E. D., Lainhart, J. E., & Anderson, J. S. (2013). Multisite functional connectivity MRI classification of autism: ABIDE results. *Frontiers in Human Neuroscience*, *7*, pp. 1–12. https://doi.org/10.3389/fnhum.2013.00599

Noppari, T. (2022). Brain structural alterations in autism and criminal psychopathy. 9, 35.

Odgers, C. L. (2009). The life-course persistent pathway of antisocial behaviour: Risks for violence and poor physical health.

Oliveira-Silva, P., Maia, L., Coutinho, J., Moreno, A. F., Penalba, L., Frank, B., Soares, J. M., Sampaio, A., & Gonçalves, Ó. F. (2023). Nodes of the default mode network implicated in the quality of empathic responses: A clinical perspective of the empathic response. *International Journal of Clinical and Health Psychology*, *23*(1), 100319. https://doi.org/10.1016/j.ijchp.2022.100319

O'Nions, E., Sebastian, C. L., McCrory, E., Chantiluke, K., Happé, F., & Viding, E. (2014). Neural bases of theory of mind in children with autism spectrum disorders and children with conduct problems and callous-unemotional traits. *Developmental Science*, *17*(5), 786–796. https://doi.org/10.1111/desc.12167

Parke, E. M., Becker, M. L., Graves, S. J., Baily, A. R., Paul, M. G., Freeman, A. J., & Allen, D. N. (2021). Social cognition in children with ADHD. *Journal of Attention Disorders*, *25*(4), 519–529. https://doi.org/10.1177/1087054718816157

Pasalich, D. S., Dadds, M. R., & Hawes, D. J. (2014). Cognitive and affective empathy in children with conduct problems: Additive and interactive effects of callous–unemotional traits and autism spectrum disorders symptoms. *Psychiatry Research*, *219*(3), 625–630. https://doi.org/10.1016/j.psychres.2014.06.025

Penny, W., Friston, K., Ashburner, J., Kiebel, S., & Nichols, T. (2006). *Statistical parametric mapping: The analysis of functional brain images* (1st ed.). Academic Press.

Pijper, J., de Wied, M., van Rijn, S., van Goozen, S., Swaab, H., & Meeus, W. (2016). Callous unemotional traits, autism spectrum disorder symptoms and empathy in boys with oppositional defiant disorder or conduct disorder. *Psychiatry Research*, *245*, 340–345. https://doi.org/10.1016/j.psychres.2016.08.053

Poustka, L., Rühl, D., Feineis-Matthews, S., Poustka, F., Hartung, M., & Bölte, S. (2015). *Diagnostische Beobachtungsskala für Autistische Störungen-2 (ADOS-2)*. Verlag Hans Huber.

Preckel, K., Kanske, P., & Singer, T. (2018). On the interaction of social affect and cognition: Empathy, compassion and theory of mind. *Current Opinion in Behavioral Sciences*, *19*, 1–6. https://doi.org/10.1016/j.cobeha.2017.07.010

R Core Team. (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.r-project.org/

Rilling, J. K., Glenn, A. L., Jairam, M. R., Pagnoni, G., Goldsmith, D. R., Elfenbein, H. A., & Lilienfeld, S. O. (2007). Neural correlates of social cooperation and non-cooperation as a function of psychopathy. *Biological Psychiatry*, *61*(11), 1260–1271. https://doi.org/10.1016/j.biopsych.2006.07.021

Rogers, J. C., & De Brito, S. A. (2016). Cortical and subcortical gray matter volume in youths with conduct problems: A meta-analysis. *JAMA Psychiatry*, *73*(1), 64–72. https://doi.org/10.1001/jamapsychiatry.2015.2423

Rogers, K., Dziobek, I., Hassenstab, J., Wolf, O. T., & Convit, A. (2007). Who cares? Revisiting empathy in Asperger syndrome. *Journal of Autism and Developmental Disorders*, *37*(4), 709–715. https://doi.org/10.1007/s10803-006-0197-8

RStudio Team. (2022). RStudio: Integrated development environment for R. *RStudio*. http://www.rstudio.com/

Sampaio, A., Soares, J. M., Coutinho, J., Sousa, N., & Gonçalves, Ó. F. (2014). The big five default brain: Functional evidence. *Brain Structure and Function*, *219*(6), 1913–1922. https://doi.org/10.1007/s00429-013-0610-y

Schilbach, L., Eickhoff, S. B., Rotarska-Jagiela, A., Fink, G. R., & Vogeley, K. (2008). Minds at rest? Social cognition as the default mode of cognizing and its putative relationship to the "default system" of the brain. *Consciousness and Cognition*, *17*(2), 457–467. https://doi.org/10.1016/j.concog.2008.03.013

Schulte-Rüther, M., Otte, E., Adigüzel, K., Firk, C., Herpertz-Dahlmann, B., Koch, I., & Konrad, K. (2017). Intact mirror mechanisms for automatic facial emotions in children and adolescents with autism spectrum disorder: Intact mirror mechanisms in Austism. *Autism Research*, *10*(2), 298–310. https://doi.org/10.1002/aur.1654

Schurz, M., Radua, J., Aichhorn, M., Richlan, F., & Perner, J. (2014). Fractionating theory of mind: A meta-analysis of functional brain imaging studies. *Neuroscience and Biobehavioral Reviews*, *42*, 9–34. https://doi.org/10.1016/j.neubiorev.2014.01.009

Schwenck, C., Mergenthaler, J., Keller, K., Zech, J., Salehi, S., Taurines, R., Romanos, M., Schecklmann, M., Schneider, W., Warnke, A., & Freitag, C. M. (2012). Empathy in children with autism and conduct disorder: Group-specific profiles and developmental aspects: Empathy in children with autism and CD. *Journal of Child Psychology and Psychiatry*, *53*(6), 651–659. https://doi.org/10.1111/j.1469-7610.2011.02499.x

Sebastian, C. L., De Brito, S. A., McCrory, E. J., Hyde, Z. H., Lockwood, P. L., Cecil, C. A. M., & Viding, E. (2016). Grey matter volumes in children with conduct problems and varying levels of callous-unemotional traits. *Journal of Abnormal Child Psychology*, *44*(4), 639–649. https://doi.org/10.1007/s10802-015-0073-0

Sebastian, C. L., Fontaine, N. M. G., Bird, G., Blakemore, S.-J., De Brito, S. A., McCrory, E. J. P., & Viding, E. (2012). Neural processing associated with cognitive and affective theory of mind in adolescents and adults. *Social Cognitive and Affective Neuroscience*, *7*(1), 53–63. https://doi.org/10.1093/scan/nsr023

Sesso, G., Brancati, G. E., Fantozzi, P., Inguaggiato, E., Milone, A., & Masi, G. (2021). Measures of empathy in children and adolescents: A systematic review of questionnaires. *World Journal of Psychiatry*, *11*(10), 876–896. https://doi.org/10.5498/wjp.v11.i10.876

Shalev, I., & Uzefovsky, F. (2020). Empathic disequilibrium in two different measures of empathy predicts autism traits in neurotypical population. *Molecular Autism*, *11*(1), 59. https://doi.org/10.1186/s13229-020-00362-1

Shalev, I., Warrier, V., Greenberg, D. M., Smith, P., Allison, C., Baron-Cohen, S., Eran, A., & Uzefovsky, F. (2022). Reexamining empathy in autism: Empathic disequilibrium as a novel predictor of autism diagnosis and autistic traits. *Autism Research*, *15*(10), 1917–1928. https://doi.org/10.1002/aur.2794

Simantov, T., Lombardo, M., Baron-Cohen, S., & Uzefovsky, F. (2021). Self-other distinction. In M. Gilead & K. N. Ochsner (Eds.), *The neural basis of mentalizing* (pp. 85–106). Springer International Publishing. https://doi.org/10.1007/978-3-030-51890-5_5

Šimić, G., Tkalčić, M., Vukić, V., Mulc, D., Španić, E., Šagud, M., Olucha-Bordonau, F. E., Vukšić, M., & Hof, P. R. (2021). Understanding emotions: Origins and roles of the amygdala. *Biomolecules*, *11*(6), 823. https://doi.org/10.3390/biom11060823

Simonoff, E., Elander, J., Holmshaw, J., Pickles, A., Murray, R., & Rutter, M. (2004). Predictors of antisocial personality: Continuities from childhood to adult life. *British Journal of Psychiatry*, *184*(2), 118–127. https://doi.org/10.1192/bjp.184.2.118

Smith, A. (2006). Cognitive empathy and emotional empathy in human behavior and evolution. *The Psychological Record*, *56*(1), 3–21. https://doi.org/10.1007/BF03395534

Smith, A. (2009). The empathy imbalance hypothesis of autism: A theoretical approach to cognitive and emotional empathy in autistic development. *The Psychological Record*, *59*(3), 489–510. https://doi.org/10.1007/BF03395675

Smith, S. M., & Nichols, T. E. (2009). Threshold-free cluster enhancement: Addressing problems of smoothing, threshold dependence and localisation in cluster inference. *NeuroImage*, *44*(1), 83–98. https://doi.org/10.1016/j.neuroimage.2008.03.061

Squillaci, M., & Benoit, V. (2021). Role of callous and unemotional (CU) traits on the development of youth with behavioral disorders: A systematic review. *International Journal of Environmental Research and Public Health*, *18*(9), 4712. https://doi.org/10.3390/ijerph18094712

Stern, J. A., Botdorf, M., Cassidy, J., & Riggins, T. (2019). Empathic responding and hippocampal volume in young children. *Developmental Psychology*, *55*, 1908–1920. https://doi.org/10.1037/dev0000684

Sterzer, P., Stadler, C., Krebs, A., Kleinschmidt, A., & Poustka, F. (2005). Abnormal neural responses to emotional visual stimuli in adolescents with conduct disorder. *Biological Psychiatry*, *57*(1), 7–15. https://doi.org/10.1016/j.biopsych.2004.10.008

Thakkar, K. N., Polli, F. E., Joseph, R. M., Tuch, D. S., Hadjikhani, N., Barton, J. J. S., & Manoach, D. S. (2008). Response monitoring, repetitive behaviour and anterior cingulate abnormalities in autism spectrum disorders (ASD). *Brain*, *131*(9), 2464–2478. https://doi.org/10.1093/brain/awn099

Uribe, C., Puig-Davi, A., Abos, A., Baggio, H. C., Junque, C., & Segura, B. (2019). Neuroanatomical and functional correlates of cognitive and affective empathy in young healthy adults. *Frontiers in Behavioral Neuroscience*, *13*, 85. https://doi.org/10.3389/fnbeh.2019.00085

Uzefovsky, F., & Knafo-Noam, A. (2016). Empathy development throughout the life span. In *Social Cognition* (pp. 89–115). Routledge. https://doi.org/10.4324/9781315520575-12

van Buuren, S., & Groothuis-Oudshoorn, K. (2011). Mice: Multivariate imputation by chained equations in R. *Journal of Statistical Software*, *45*(3). https://doi.org/10.18637/jss.v045.i03

van der Zee, E., & Derksen, J. J. L. (2020). Reconsidering empathy deficits in children and adolescents with autism. *Journal of Developmental and Physical Disabilities*, *32*(1), 23–39. https://doi.org/10.1007/s10882-019-09669-1

Van Overwalle, F., & Baetens, K. (2009). Understanding others' actions and goals by mirror and mentalizing systems: A meta-analysis. *NeuroImage*, *48*(3), 564–584. https://doi.org/10.1016/j.neuroimage.2009.06.009

Vehtari, A., Gelman, A., & Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and Computing*, *27*(5), 1413–1432. https://doi.org/10.1007/s11222-016-9696-4

Vijayakumar, N., Mills, K. L., Alexander-Bloch, A., Tamnes, C. K., & Whittle, S. (2018). Structural brain development: A review of methodological approaches and best practices. *Developmental Cognitive Neuroscience*, *33*, 129–148. https://doi.org/10.1016/j.dcn.2017.11.008

Vilas, S. P., Reniers, R. L. E. P., & Ludlow, A. K. (2021). An investigation of Behavioural and self-reported cognitive empathy deficits in adolescents with autism Spectrum disorders and adolescents with Behavioural difficulties. *Frontiers in Psychiatry*, *12*, 717877. https://doi.org/10.3389/fpsyt.2021.717877

von Polier, G. G., Greimel, E., Konrad, K., Großheinrich, N., Kohls, G., Vloet, T. D., Herpertz-Dahlmann, B., & Schulte-Rüther, M. (2020). Neural correlates of empathy in boys with early onset conduct disorder. *Frontiers in Psychiatry*, *11*, 178. https://doi.org/10.3389/fpsyt.2020.00178

Waller, R., Hawes, S. W., Byrd, A. L., Dick, A. S., Sutherland, M. T., Riedel, M. C., Tobia, M. J., Bottenhorn, K. L., Laird, A. R., & Gonzalez, R. (2020). Disruptive behavior problems, callous-unemotional traits, and regional gray matter volume in the adolescent brain and cognitive development study. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *5*(5), 481–489. https://doi.org/10.1016/j.bpsc.2020.01.002

Waller, R., & Hyde, L. W. (2018). Callous-unemotional behaviors in early childhood: The development of empathy and prosociality gone awry. *Current Opinion in Psychology*, *20*, 11–16. https://doi.org/10.1016/j.copsyc.2017.07.037

Waller, R., Hyde, L. W., Grabell, A. S., Alves, M. L., & Olson, S. L. (2015). Differential associations of early callous-unemotional, oppositional, and ADHD behaviors: Multiple domains within early-starting conduct problems? *Journal of Child Psychology and Psychiatry*, *56*(6), 657–666. https://doi.org/10.1111/jcpp.12326

Waller, R., Wagner, N. J., Barstead, M. G., Subar, A., Petersen, J. L., Hyde, J. S., & Hyde, L. W. (2020). A meta-analysis of the associations between callous-unemotional traits and empathy, prosociality, and guilt. *Clinical Psychology Review*, *75*, 101809. https://doi.org/10.1016/j.cpr.2019.101809

Walter, H. (2012). Social cognitive neuroscience of empathy: Concepts, circuits, and genes. *Emotion Review*, *4*(1), 9–17. https://doi.org/10.1177/1754073911421379

Wechsler, D. (2012a). *Wechsler adult intelligence scale—Fourth edition [Data set]*. American Psychological Association. https://doi.org/10.1037/t15169-000

Wechsler, D. (2012b). *Wechsler intelligence scale for children [Data set]* (Fourth ed.). *American Psychological Association*. https://doi.org/10.1037/t15174-000

Wilke, M., Altaye, M., Holland, S. K., & The CMIND Authorship Consortium. (2017). CerebroMatic: A versatile toolbox for spline-based MRI template creation. *Frontiers in Computational Neuroscience*, *11*, pp. 1–18. https://www.frontiersin.org/articles/10.3389/fncom.2017.00005

Willoughby, M. T., Mills-Koonce, W. R., Gottfredson, N. C., & Wagner, N. J. (2014). Measuring callous unemotional behaviors in early childhood: Factor structure and the prediction of stable aggression in middle childhood. *Journal of Psychopathology and Behavioral Assessment*, *36*(1), 30–42. https://doi.org/10.1007/s10862-013-9379-9

Winters, D. E., Pruitt, P. J., Fukui, S., Cyders, M. A., Pierce, B. J., Lay, K., & Damoiseaux, J. S. (2021). Network functional connectivity underlying dissociable cognitive and affective components of empathy in adolescence. *Neuropsychologia*, *156*, 107832. https://doi.org/10.1016/j.neuropsychologia.2021.107832

Yerys, B. E., Gordon, E. M., Abrams, D. N., Satterthwaite, T. D., Weinblatt, R., Jankowski, K. F., Strang, J., Kenworthy, L., Gaillard, W. D., & Vaidya, C. J. (2015). Default mode network segregation and social deficits in autism spectrum disorder: Evidence from non-medicated children. *NeuroImage: Clinical*, *9*, 223–232. https://doi.org/10.1016/j.nicl.2015.07.018

Ypma, R. J. F., Moseley, R. L., Holt, R. J., Rughooputh, N., Floris, D. L., Chura, L. R., Spencer, M. D., Baron-Cohen, S., Suckling, J., Bullmore, E. T., & Rubinov, M. (2016). Default mode hypoconnectivity underlies a sex-related autism Spectrum. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *1*(4), 364–371. https://doi.org/10.1016/j.bpsc.2016.04.006

## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

**How to cite this article:** Tkalcec, A., Bierlein, M., Seeger-Schneider, G., Walitza, S., Jenny, B., Menks, W. M., Felhbaum, L. V., Borbas, R., Cole, D. M., Raschle, N., Herbrecht, E., Stadler, C., & Cubillo, A. (2023). Empathy deficits, callous-unemotional traits and structural underpinnings in autism spectrum disorder and conduct disorder youth. *Autism Research*, *16*(10), 1946–1962. https://doi.org/10.1002/aur.2993