**Additional Information Regarding Covariates**

To account for potential demographic or developmental effects, we included the following covariates in all fMRI analyses: (a) parent-reported annual family income; (b) youth age (months); (c) self-reported gender; and (d) self-reported pubertal development, using the Pubertal Development Scale (Murray, Lopez-Duran, Mitchell, Monk, & Hyde, 2020; Petersen, Crockett, Richards, & Boxer, 1988). Self-reported race/ethnicity, was also included as a covariate in all models. We covaried for race/ethnicity, a social construct, to address differences in exposures to personal and systemic racism and other unequal exposures in youth of color. Youth-reported ethnic identity from the Multigroup Ethnic Identity Measure (Phinney, 2010). For two youth, self-reported ethnic identity was missing and was coded using the parent-report of the child’s ethnicity/race from the demographic interview. Race/ethnicity was then coded dichotomously into all other reported race/ethnicities vs. non-Hispanic White/European to account for youth likely versus unlikely to experience marginalization. Finally, to account for potential effects of intellectual ability, we included standardized scores from Peabody Picture Vocabulary Test (Dunn & Dunn, 1997) as a covariate in all models. Because intellectual ability was not assessed at the age 15 study visit in the Study of Adolescent Neural Development (SAND) or in the longitudinal Fragile Families and Child Wellbeing Study (FFCWS), we used the PPVT from the age 9 assessment wave. Two subjects did not complete the age 9 assessment wave, so PPVT scores from the age 5 assessment wave were used. Four subjects did not complete the age 5 and age 9 assessment waves, and thus were excluded from analyses. Results with and without intellectual ability included as a covariate were highly similar.

**Figure 1**



**Modified Monetary Incentive Delay task.** A schematic of a single MID trial. Trial type was indicated by a up arrow, down arrow or a horizontal double arrow to indicate reward, loss and neutral trials, respectively (2 s). After a variable delay (2–2.5 s) a white square (target) appeared. Participants were instructed to respond as quickly as possible to the target. A fixation cross appeared that included a delay (2 s) and a catch-up period to account for variability in participant response. Feedback was presented (1.65 s), followed by a jittered inter-trial interval (2, 3 or 4 s). The task was modified from common versions of the MID (e.g., Casey et al., 2018; Knutson, Fong, Adams, Varner, & Hommer, 2001) by adding a jittered intertrial interval to allow for more temporal separation of anticipation and consumption phases of reward and loss processing. Figure reproduced, with permission from (Murray et al., 2020).

**Supplemental Table 1: Summary of Available Data for Analyses**

|  |  |  |
| --- | --- | --- |
|  | **Number lost** | **Participants with data** |
| **Original sample** |  | **237** |
| **Sample with imaging data** |  |  |
| * Refused MRI
 | 7  |  |
| * Exceeded MRI table weight limit/couldn’t fit in scanner
 | 5 |  |
| * Medical restriction
 | 3 |  |
| * Braces or other metal in body
 | 13 |  |
| * Risk of pregnancy
 | 1 |  |
| * Missed scanning appointment
 | 1 |  |
| * Excluded for diagnosis of Autism Spectrum Disorder
 | 2 |  |
| * Incomplete fMRI data
 | 12 |  |
|  |  |  |
| **Total lost** | **44** | **193** |
| **Sample with usable imaging data** |  |  |
| * Task administration issue (i.e., wrong version, wrong hand)
 | 2 |  |
| * fMRI scan quality issues (distortion, artifact, signal drop out)
 | 17 |  |
| * Low ventral striatum coverage (<70%)
 | 7 |  |
| * Motion outlier (>5% TRs with ART)
 | 4 |  |
| * Poor Task Performance (<6 trials per outcome condition)
 | 26 |  |
| * Poor Task Performance (>10 consecutive trials without a recorded button press)
 | 6 |  |
| * Activation outlier
 | 4 |  |
| * Missing intellectual ability measure
 | 4 |  |
|  |  |  |
| **Total lost** | **70** | **123** |

***Note.*** Participants with complete and usable MRI data from the full sample. Consistent with previous work in this sample (Murray et al., 2020), fMRI data were excluded if there was signal drop out in the VS ROI (< 70% coverage) or in reward-related limbic and prefrontal regions via visual inspection of individual whole brain maps. Four subjects were identified with large outlier parameter estimates (±>3 s.d. from sample mean) in contrasts of interest. For these participants, individual functional scans were further inspected to confirm either a few large or many small movements that caused abnormal parameter estimates. Analyses including these subjects is presented in Supplemental Table 5. Behavioral data from the MID task were analyzed to ensure sufficient responding during the task. Youth with < 6 trials of each outcome were excluded due to poor task responding. Also, for participants with <10 trials per outcome, behavioral data were visually inspected to ensure consistent participant engagement.

**Supplemental Table 2: Descriptive Statistics of Demographic Measures for the Final Analytic Sample**

|  |  |
| --- | --- |
| Measure | Count (%) |
| Adolescent Gender |  |
| * Male
 | 50 (40.7) |
| * Female
 | 73 (59.3) |
| Adolescent Self-Reported Race |  |
| * Black / African American
 | 93 (75.6) |
| * White / Caucasian
 | 15 (12.2) |
| * More than one race
 | 5 (4.1) |
| * Other Non-Hispanic Groups
 | 5 (4.1) |
| Adolescent Self-Reported Ethnicity |  |
| * Not Hispanic
 | 118 (95.9) |
| * Hispanic
 | 5 (4.1) |
| Measure | **Range****Mean (SD)** |
| * Age (Years)
 | 15.0-17.6 15.87 (0.53) |

**Supplemental Table 3: Descriptive Statistics and Bivariate Correlations between Measures Included in Antisocial Behavior Factor Score**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **CBCL Aggression** | **CBCL****Rule-Breaking** | **SRD Total Score** | **KSADS ODD/CD Symptoms** |
| **CBCL Rule-Breaking** | .81\*\*\* |  |  |  |
| **SRD Total Score** **(no drug items)** | .39\*\*\* | .30\*\*\* |  |  |
| **KSADS ODD/CD Symptom Count** | .64\*\*\* | .61\*\*\* | .47\*\*\* |  |
| ***M (SD)*** | 3.84(2.82) | 2.00(4.79) | 5.77 (6.88) | 4.85(9.04) |
| **Range** | 0-25 | 0-18 | 0-44 | 0-51 |
| **Factor Loading** | .88\*\*\* | .93\*\*\* | .39\*\*\* | .69\*\*\* |

***Note.***†p < .10, \*p <.05; \*\*p <.01; \*\*\*p <.001. CBCL= Child Behavior Checklist; SRD = Self-Report of Delinquency; KSADS = Kiddie Schedule for Affective Disorders and Schizophrenia; ODD = oppositional defiant disorder; CD = conduct disorder; df = degrees of freedom; TLI = Tucker–Lewis index; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean residual. Correlations were computed for whole sample (n = 237). Analyses performed using maximum likelihood estimation with robust standard errors (which can accommodate skewness) in Mplus version 7.3 (Muthén & Muthén, 2014). Chi-Square test of model fit = 2.67, df=1, p=.10; CFI=.99, TLI=.96, RMSEA=.08, SRMR=.01. Based on modification indices, two scales’ residuals (SRD Total score and KSADS ODD/CD Symptom Count) were allowed to correlate.

**Supplemental Table 4: Descriptive Statistics and Bivariate Correlations between Measures Included in Callous-Unemotional Traits Factor Score**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **ICU Parent Total** | **ICU** **Self** **Total** | **Limited Prosocial Emotions Symptoms** |
| **ICU Parent-Report Total Score** |  |  |  |
| **ICU Self-Report Total Score** | .13\* |  |  |
| **CAPE/KSADS Limited Prosocial Emotions Symptom Count** | .35\*\*\* | .29\*\*\* |  |
| ***M (SD)*** | 18.99(8.99) | 21.78(8.24) | .97 (2.69) |
| **Range** | 1-52 | 4-44 | 0-16 |
| **Factor Loading** | .40\*\*\* | .35\*\*\* | .86\*\*\* |

***Note.***†p < .10, \*p <.05; \*\*p <.01; \*\*\*p <.001. ICU = Inventory of Callous-Unemotional Traits; KSADS = Kiddie Schedule for Affective Disorders and Schizophrenia; CAPE = Clinical Assessment of Prosocial Emotions; df = degrees of freedom; TLI = Tucker-Lewis index; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean residual. Consistent with prior studies that have used the ICU, we used a total score for 22 of the original 24 items dropping two items based on an examination of polychoric inter-item correlations (Waller et al., 2015). Correlations were computed for whole sample (n = 237). Measures of CU traits were significantly skewed. Analyses performed using maximum likelihood estimation with robust standard errors (which can accommodate skewness) in Mplus version 7.3 (Muthén & Muthén, 2014). Model was fully saturated.

**Supplemental Table 5: Associations Between Study Variables**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **AB** | **CU traits** | **Pubertal Development** | **Age** | **CBCL Rule Breaking** | **CBCL Aggression** | **Verbal Ability** | **Annual Income** |
| **AB Factor** | 1 |  |  |  |  |  |  |  |
| **CU Traits Factor** | 0.67\*\*\* | 1 |  |  |  |  |  |  |
| **Pubertal Development** | -0.17 | -0.15 | 1 |  |  |  |  |  |
| **Age (months)** | 0.12 | 0.18 | 0.00 | 1 |  |  |  |  |
| **CBCL Rule Breaking** | 0.96\*\*\* | 0.69\*\*\* | -0.16 | 0.14 | 1 |  |  |  |
| **CBCL Aggression** | 0.92\*\*\* | 0.54\*\*\* | -0.18 | 0.07 | 0.80\*\* | 1 |  |  |
| **Verbal Ability** | -0.05 | -0.03 | 0.05 | -0.05 | -0.04 | -0.08 | 1 |  |
| **Annual Income** | -0.05 | -0.24\*\* | -0.08 | 0.02 | -0.09 | 0.04 | 0.20\* | 1 |

***Note.*** Correlations between antisocial behavior and callous unemotional traits factor scores and demographic variables included in analyses. Verbal ability was measured using the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997). Pearson correlation coefficients are presented, with the exception of annual family income variable, which was ordinal, thus Spearman’s rho is reported. AB = antisocial behavior, CU = callous unemotional traits, CBCL = Child Behavior Checklist. \**p* < 0.05, \*\* *p* < 0.01, \*\*\* *p* < 0.001

**Supplemental Table 5: Neural Reactivity during Reward and Loss Processing in Antisocial Behavior and Callous Unemotional Traits with fMRI Outliers Included**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ***t*** | **Cluster Size** | **MNI Coordinates** | **Brain Region** |
| **Loss Anticipation > Loss Outcome** |
| No significant clusters |
| **Reward Win> No Win** |
| No significant clusters |
| **Loss Anticipation > Loss Outcome** |
| **AB x CU Traits** | 4.62 | 388 | 32 -66 40 | Precuneus, angular gyrus  |
| **Loss Outcome > No Loss** |
| **AB** | -6.49 | 1254 | -34 -54 52 | Inferior and superior parietal lobule |
|  | -5.99 | 1726 | 20 -62 52 | Superior and inferior parietal lobule |
|  | -5.77 | 1446 | -44 12 24 | Inferior frontal operculum, inferior frontal gyrus |
|  | -5.64 | 432 | 22 -6 48 | Superior frontal gyrus, precentral gyrus |
|  | -5.28 | 1328 | 48 38 12 | Middle frontal gyrus, precentral gyrus |
|  | -4.83 | 460 | -42 -62 -16 | Fusiform gyrus, cerebellum, lingual gyrus |
|  | -4.67 | 105 | 58 -48 -12 | Inferior temporal gyrus |
|  | -4.64 | 133 | -10 -36 6 | Posterior cingulate |
|  | -4.62 | 355 | 52 -20 16 | Rolandic operculum |
|  | -4.34 | 157 | 2 42 38 | Superior medial frontal gyrus |
| **CU Traits** | -4.79 | 102 | -42 -64 8 | Middle temporal gyrus |
|  | -4.70 | 470 | -44 18 40 | Middle frontal gyrus, precentral gyrus |
|  | -4.24 | 135 | 36 8 34 | Inferior frontal operculum |
| **AB x CU Traits** | -6.71 | 4654 | 24 -58 62 | Superior parietal lobule |
|  | -6.68 | 182 | -52 14 20 | Inferior frontal operculum |
|  | -6.58 | 1202 | -50 12 28 | Inferior frontal operculum, middle frontal gyrus |
|  | -5.36 | 450 | 50 34 14 | Middle and superior frontal gyri |
|  | -5.05 | 143 | 56 -62 -2 | Inferior temporal gyrus |
|  | -4.54 | 700 | 0 36 14 | Anterior cingulate, medial superior frontal gyrus |
|  | -4.37 | 96 | 16 4 26 | Caudate |
|  | -4.35 | 92 | -42 -64 -16 | Fusiform gyrus |
|  | -4.06 | 105 | -20 -16 28 | Caudate |

***Note.*** Associations between AB and CU traits factors and neural response to reward and loss including fMRI outliers. Four youths were excluded from the analyses due to excessive movement-related signal artifacts that could potentially influence the findings. Analyses including these subjects (total n=127) controlled for demographic variables (age, gender, pubertal status, annual family income, self-reported race, and verbal ability) and were significant at *p* < .001 and α=.05., cluster threshold k=81 and were highly similar to those reported in the main text.

**Supplemental Table 6: Neural Reactivity during Reward and Loss Processing in Antisocial Behavior and Callous Unemotional Traits**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ***t*** | **Cluster Size** | **MNI Coordinates** | **Brain Region** |
| **Reward Anticipation > Reward Outcome** |
| No significant clusters |
| **Reward Win> No Win** |
| No significant clusters |
| **Loss Anticipation > Loss Outcome** |
| **AB x CU Traits** **(no covariates)** | 4.72 | 588 | 30 -66 42 | Precuneus, angular gyrus  |
| **Loss Outcome > No Loss** |
| **AB** **(no covariates)** | -6.49 | 3933 | -18 -68 56 | Inferior and superior parietal lobe |
|  | -6.21 | 1471  | -44 12 24 | Inferior frontal gyrus |
|  | -5.71 | 800 | 48 38 12 | Inferior and middle frontal gyrus |
|  | -5.08 | 263 | 22 -6 48 | Precentral gyrus, superior frontal gyrus |
|  | -4.92 | 296 | 2 40 38 | Medial superior frontal gyrus, supplementary motor area |
|  | -4.61 | 130 | -8 -38 6 | Precuneus |
|  | -4.57 | 117 | 18 10 20 | Caudate |
|  | -4.06 | 207 | -20 -72 -16 | Cerebellum, lingual gyrus |
|  | -3.82 | 105 | -42 -64 -18 | Fusiform gyrus |
| **CU Traits** | -4.88 | 95 | -42 -64 8 | Middle temporal gyrus |
| **(no covariates)** | -4.05 | 252 | -42 10 36 | Middle frontal gyrus, precentral gyrus |
|  | -3.75 | 122 | -32 -54 50 | Inferior and Superior parietal lobe |
|  | -3.58 | 87 | -44 36 26 | Middle frontal gyrus |
| **AB** **(with CU traits & demographic covariates)** | -6.66 | 2829 | 24 -66 52 | Superior and inferior parietal lobule |
| -6.51 | 830 | 48 38 12 | Inferior and middle frontal gyrus |
| -5.02 | 414 | -46 12 24 | Inferior frontal gyrus, precentral |
| -4.99 | 421 | 22 -8 48 | Superior and inferior parietal lobule |
|  | -4.69 | 227 | 2 40 40 | Medial superior frontal gyrus |
|  | -4.29 | 103 | -8 -38 58 | Precuneus, paracentral lobule |
|  | -4.27 | 209 | 50 6 30 | Precentral gyrus |
|  | -4.24 | 114 | 16 8 22 | Caudate |
| **CU Traits** **(with AB & demographic covariates)** | 4.22 | 127 | 40 38 14 | Inferior and middle frontal gyrus |
| **AB x CU Traits** **(no covariates)** | -6.92 | 1029 | -50 10 28 | Inferior and middle frontal gyrus |
|  | -6.74 | 2892 | 24 -58 62 | superior parietal lobule, precuneus, angular gyrus |
|  | -6.53 | 176 | -52 14 20 | Inferior frontal operculum |
|  | -5.90 | 603 | -30 -48 40 | Inferior and superior parietal lobe |
|  | -5.50 | 135 | 56 -62 -2 | Inferior temporal gyrus |
|  | -5.23 | 436 | 48 4 22 | Inferior frontal operculum |
|  | -4.98 | 311 | 48 38 12 | Inferior frontal gyrus |
|  | -4.62 | 118 | -22 18 14 | Caudate |
|  | -4.44 | 169 | 0 34 16 | Anterior cingulate |
|  | -4.28 | 224 | -4 36 14 | Anterior cingulate, medial superior frontal gyrus |
|  | -3.99 | 82 | 28 12 18 | undefined |

***Note.*** Associations between AB and CU traits factors and neural response to reward and loss. Additional analyses were conducted to thoroughly assess neural response to reward and loss in AB and CU traits. Analyses tested zero-order associations (i.e., AB without covariates, CU traits without covariates, ABxCU traits interaction without covariates) and when accounting for the overlap between AB and CU traits (i.e., AB controlling for CU traits and demographic covariates and vice versa). Results were largely similar to those reported in the main text, however negative associations between CU traits and Loss Outcome>No Loss were not significant when controlling for overlap with AB, and were instead associated with increased middle frontal gyrus activity to Loss Outcome > No Loss.

**Supplemental Table 7: Associations between CBCL Aggression and Rule Breaking Subscales and Neural Reactivity during Reward and Loss Processing**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ***t*** | **Cluster Size** | **MNI Coordinates** | **Brain Region** |
| **Loss Anticipation > Loss Outcome** |
| No significant clusters |
| **Reward Win> No Win** |
| No significant clusters |
| **Loss Anticipation > Loss Outcome** |
| No significant clusters |
| **Loss Outcome > No Loss** |
| **Rule Breaking** | -7.24 | 11166 | -18 -66 56 | Superior and inferior parietal lobe, inferior frontal gyrus  |
|  | -5.83 | 1887 | -42 -64 -16 | Fusiform gyrus, precuneus, superior occipital lobe |
|  | -5.56 | 876 | 58 -48 -12 | Inferior and middle temporal gyri, inferior occipital gyrus |
|  | -5.28 | 377 | 2 42 38 | Superior medial frontal gyrus, supplementary motor area |
|  | -4.94 | 114 | 18 12 20 | Caudate |
|  | -4.91 | 129 | 22 -96 6 | Superior occipital lobe |
|  | -3.84 | 146 | 8 38 16 | Anterior cingulate |
|  | -3.82 | 110 | 30 6 16 | Insula |
| **Rule Breaking**  | -6.15 | 2204 | 40 -16 20 | Rolandic operculum |
| **(controlling for Aggression)** | -6.00 | 1456 | -50 14 30 | Inferior frontal gyrus, inferior frontal operculum, supramarginal gyrus |
|  | -5.05 | 309 | -20 -68 58 | Superior and inferior parietal lobe |
|  | -4.84 | 122 | -42 -64 -14 | Fusiform gyrus |
|  | -4.78 | 896 | 48 -48 28 | Angular gyrus, superior parietal lobe |
|  | -4.57 | 221 | 52 -66 0 | Middle and inferior temporal gyri |
|  | -4.30 | 129 | -8 -36 -12 | Cerebellum, Lingual gyrus, hippocampus |
|  | -4.28 | 206 | 34 -82 -12 | Inferior occipital lobe |
|  | -4.12 | 98 | 6 -76 42 | Precuneus |
| **Aggression** | -5.44 | 1046 | -36 -54 52 | Inferior and superior parietal lobe, precuneus |
|  | -5.34 | 1093 | 20 -62 52 | Superior and inferior parietal lobe |
|  | -4.97 | 338 | 48 38 12 | Inferior and middle frontal gyri |
|  | -4.73 | 365 | 22 -6 48 | Superior frontal gyrus, precentral gyrus |
|  | -4.72 | 392 | 2 38 44 | Superior medial frontal gyrus, supplementary motor area |
|  | -4.63 | 770 | -46 30 28 | Inferior frontal gyrus, inferior frontal operculum |
|  | -4.21 | 217 | 48 8 30 | Precentral gyrus, middle frontal gyrus, inferior frontal operculum |
|  | -4.06 | 89 | 16 -94 12 | Cuneus |
|  | -4.01 | 85 | -48 52 12 | Middle frontal gyrus |
|  | -3.75 | 139 | -40 -64 -18 | Fusiform gyrus, cerebellum |
| **Aggression** | No significant clusters |  |
| **(controlling for Rule Breaking)** |  |  |  |  |

**References**

Casey, B., Cannonier, T., Conley, M. I., Cohen, A. O., Barch, D. M., Heitzeg, M. M., . . . Garavan, H. (2018). The adolescent brain cognitive development (ABCD) study: imaging acquisition across 21 sites. *Developmental cognitive neuroscience, 32*, 43-54. doi:10.1016/j.dcn.2018.03.001

Dunn, L. M., & Dunn, L. M. (1997). Peabody Picture Vocabulary Test (3rd ed.).

Knutson, B., Fong, G. W., Adams, C. M., Varner, J. L., & Hommer, D. (2001). Dissociation of reward anticipation and outcome with event-related fMRI. *Neuroreport, 12*(17), 3683-3687. doi:10.1097/00001756-200112040-00016

Murray, L., Lopez-Duran, N. L., Mitchell, C., Monk, C. S., & Hyde, L. W. (2020). Neural mechanisms of reward and loss processing in a low-income sample of at-risk adolescents. *Social cognitive and affective neuroscience, 15*(12), 1310-1325. doi:10.1093/scan/nsaa157

Muthén, L. K., & Muthén, B. O. (2014). Mplus 7.3. Los Angeles, CA: Muthén & Muthén.

Petersen, A. C., Crockett, L., Richards, M., & Boxer, A. (1988). A self-report measure of pubertal status: Reliability, validity, and initial norms. *Journal of Youth and Adolescence, 17*(2), 117-133. doi:doi.org/10.1007/BF01537962

Phinney, J. S. (2010). *Multigroup Ethnic Identity Measure (MEIM)*: Springer.

Waller, R., Wright, A. G., Shaw, D. S., Gardner, F., Dishion, T. J., Wilson, M. N., & Hyde, L. W. (2015). Factor structure and construct validity of the parent-reported Inventory of Callous-Unemotional Traits among high-risk 9-year-olds. *Assessment, 22*(5), 561-580. doi:10.1177/1073191114556101