Affective theory of mind impairments linked with callous-unemotional traits implicate cognitive control: A pre-registered double-blind randomized controlled trial with a dual-task paradigm

Drew E. Winters[a], Juliet Spitz[a], Kristen Raymond[a], Crystal Natvig[a], Rebecca Waller[b], Susan K. Mikulich-Gilbertson[a], Joseph T. Sakai[a]

[a] Department of Psychiatry, University of Colorado School of Medicine, Anschutz Medical Campus, Aurora, CO, USA
[b] Department of Psychology, University of Pennsylvania, Philadelphia, PA, USA

Corresponding author: Drew Winters
drewEwinters@gmail.com

ORCID ID - Drew E. Winters: 0000-0002-0701-9658
Crystal Natvig: 0000-0003-0598-9236
Rebecca Waller: 0000-0002-5069-1183
Susan Mikulich: 0000-0001-9210-8884
Joseph T. Sakai: 0000-0003-1600-6100

Drew E Winters, PhD. was supported by a training grant from National Institutes of Mental Health, T32MH015442
Joseph T. Sakai was supported by a grant from National Institute of Drug Addiction, UG3DA054746
Rebecca Waller was supported by grants from National Institutes of Mental Health, R01 MH125904 and R21MH126162

Number of words (main text): 7,147
Number of figures: 4
Number of tables: 4
Number of supplementary figures: 5
Number of supplementary tables: 18

Abstract

Background: Antisocial behavior in youth can encompass both conduct problems (CP; e.g., aggression, rule-breaking) and callous-unemotional (CU) traits (i.e., limited empathy, remorse, and guilt). CP are associated with pronounced and broad cognitive difficulties whereas CU traits have stronger links to disrupted affective theory of mind (ToM) and more specific cognitive difficulties involving cognitive control. Cognitive control difficulties have been linked to affective ToM among early adolescents with elevated CU traits, suggesting an interaction between cognitive and affective processing that are unique to CU traits. Here we sought to improve on those initial findings by leveraging a randomized dual-task (within-trial) design to replicate and extend prior findings.

Trial design: The preregistered study leveraged a double-blind randomized controlled trial using a dual-task design. The dual-task used an inhibitory processing task as a secondary task to impose additional demands on cognitive control implicated in ToM to compete with a primary ToM task with cognitive, affective, and physical ToM condition. Participants were randomized into control and test conditions using a permuted block randomization stratified by sex at birth and severity of CU traits. The order of single ToM task or dual-task was counterbalanced to test within subject effects of cognitive control on affective ToM inferences.

Methods: A total of 85 participants (47% female) were used in the final analysis. Primary and preregistered hypotheses were tested using a repeated measure random effect model that accounted for individual variance and tested fixed effect interactions for CU and CP with group across time. Outcomes tested involved change in accuracy and reaction time from single ToM to dual-task. Secondary analysis examined contrasts between ToM trial types, dual-task effect, and single ToM task performance as well as associations with antisocial behaviors.

Results: CU traits were independently associated with decrements in affective ToM from single to dual-task for both accuracy and reaction time, as well as secondary contrast tests when comparing affective > physical and cognitive trials. CU traits were also related to greater dual-task effects indicating greater difficulty in ToM after taxing cognitive control. CP were related to decrements at baseline ToM task performance but were not associated with changes after taxing cognitive control during the dual-task. Importantly, a subset of participants appeared to be resilient to dual-task effects reported lower baseline antisocial behavior even at elevated CU traits.

Conclusions: Resource limitations for cognitive control in those elevated in CU traits is an important mechanism underlying difficulty utilizing affective data from the environment to inform social behavior. Those less vulnerable to additional demands on cognitive control reported fewer antisocial acts even at higher CU traits. Overall, findings suggest specific cognitive-affective interactions that relate to CU traits and explain real world antisocial behavior. This is a novel mechanism outside of the traditional cognition or affect etiologies that may indicate a developmentally specific mechanism critical in the study and treatment of youth antisocial phenotypes and development of psychopathy in adulthood.

Keywords: callous-unemotional traits, conduct, adolescence, cognitive control, theory of mind

Theory of mind (ToM) refers to the ability to recognize and infer others mental (cognitive ToM) and emotional (affective ToM) state (Shamay-Tsoory et al., 2010). Greater ToM is linked to actions that aim to help others (i.e., prosocial behavior) and inversely related to acts that violate laws and human rights or harm others (i.e., antisocial behavior; Imuta et al., 2016). Antisocial behavior in youth encompasses conduct problems (CP; i.e., antisocial patterns of disruptive and aggressive behaviors linked with antisocial lifestyle features in adult psychopathy) and callous-unemotional (CU) traits (i.e., profound impairments in prosocial emotions of guilt, remorse, and empathy linked with affective deficits in adult psychopathy; Frick & White, 2008). These phenotypes are a public health concern due to a disproportionate link with criminal convictions for serious crimes (> 50% of convictions), aggression, and substance use as well as an increased economic burden on the public compared to those without CP or CU (Blair, Leibenluft, & Pine, 2014; Foster, Jones, & Group, 2005; Gatner et al., 2023; Kahn, Byrd, & Pardini, 2013; Rivenbark et al., 2018; Sakki et al., 2023; Winters et al., 2020).

CP and CU traits often co-occur but are conceptually distinct, can present independently, and are associated with different types of antisocial outcomes (Baskin-Sommers et al., 2015). Given this related but distinct relationship, it is not supported that functional impairments differentiate these phenotypes in specific processes rather than broad and general domains of impairment. For example, where general ToM deficits account for variance in both CP (Holl, Vetter, & Elsner, 2021) and CU traits (Gillespie et al., 2018; Song et al., 2016), CU traits have a specific link with affective ToM impairments (Song et al., 2023). Relatedly, where general cognitive deficits are more strongly linked to CP (Baskin-Sommers et al., 2022; Gillespie et al., 2022), CU traits have a specific link with deficits in cognitive control (i.e., regulating behavior by inhibition, monitoring context, resolving conflicts, and organizing actions; Botvinick et al.,

2001) during conflict between competing demands (Gluckman, Hawes, & Russell, 2016; Drew E. Winters et al., 2023). These cognition and ToM distinctions between CP and CU traits are important considerations clinically, as the demonstrated limitations in efficacy of available treatments indicate a need to refine phenotypic specific targets aimed to redress underlying antisocial etiology (see reviews: Perlstein et al., 2023; White et al., 2022).

Traditional etiological perspectives on CU traits have bifurcated focus on either affect (Blair, 2005; Lykken, 2013) or cognitive (reviews: Baskin-Sommers & Newman, 2013; Glass & Newman, 2009) difficulties. This dichotomy could be resolved by considering substantive evidence from other fields demonstrating interactions between cognition and affect in the etiology of behavior (e.g., Brosch et al., 2013; reviews: Pessoa, 2008; Pessoa, 2010). For example, affective deficit models propose that CU traits arise from deficient empathy that precludes learning from negative environmental cues (e.g., harm or punishment, including anger, fear, and sadness expressed by others: Blair, 2005; Lykken, 2013). However, this view overlooks literature showing that empathy is rooted in cognitive functioning (Krishnan et al., 2016; Waller & Wagner, 2019), affective processing interacts closely with cognitive processes in the brain (Duncan & Barrett, 2007), and that those elevated in CU have been shown to empathize accurately (e.g., Rijnders et al., 2021). In contrast, cognitive models of psychopathy in adults (e.g., response modulation hypothesis) argue that intact capacity for affective processing is impacted when stimuli fall outside primary attentional focus (Newman & Lorenz, 2003). This view has been extended into the attention bottleneck hypothesis, which suggests selective attention limits contextual information processing (Baskin-Sommers & Brazil, 2022; Tillem, Weinstein, & Baskin-Sommers, 2021). Critiques of these models question the attention model used rather than a limitation in computational resources as well as a lack of consideration of affect (Blair & Mitchell, 2009). Additions to the cognitive models may have redressed these concerns as affect processing has been included in cognitive models implicating a cognitive-affective interaction (e.g., Baskin-Sommers et al., 2022; Baskin-Sommers & Newman, 2013) and the load on cognitive resource has been recognized as an important feature for disentangling cognition and affect (Baskin-Sommers & Brazil, 2022).

However, prior work has largely focused on adult psychopathy, and we lack rigorous tests of these models in youth, which could provide insights in the developmental pathways from CP and CU traits to sever antisocial behavior and psychopathy. In particular, the notion of resource allocation for cognitive control appears particularly relevant for understanding the specific cognition-affect computations that might underpin CU traits. The computation influencing the probability of using available resources for cognitive control, named the expected value of control, balances the cost and payoff of allocating resources to processes involving control (Shenhav, Botvinick, & Cohen, 2013). This computation can include an affective value that interacts with cognitive function (cognitive control and perception), which is the point at which affect and cognition compete for resources and interact in the dual-competition model (Pessoa, 2010). This computation is hypothesized to relate to CU traits via a cognitive resource vulnerability where lower cognitive demands make resources more scarce and less probable to be allocated for processing others affect (Winters & Sakai, 2023), potentially explaining the etiological basis of CU traits such as low empathy, remorse, and guilt.

To date, a handful of studies provide insight into the link between CU traits and limitations in resources for cognitive control. In a series of behavioral studies, adolescents aged 9-13 elevated in CU traits uniquely associated with difficulties in resource availability for cognitive control (Gluckman, Hawes, & Russell, 2016; Winters & Sakai, 2023). Moreover, CU traits, but not CP, were uniquely related to difficulties allocating resources for affective ToM as competing cognitive control processes were increased (Winters & Sakai, 2023). From the neuroimaging literature, CU traits have been linked to disrupted connectivity between regions involved excepted value evaluation and attention conflict resolution (Pessoa, 2010; Shenhav, Botvinick, & Cohen, 2013). For example, among adolescents ages 13-17, CU traits have been linked to disrupted connectivity of the anterior cingulate cortex (ACC) with the lateral prefrontal cortices (Drew E Winters, Jules R Dugré, et al., 2023; Winters, Guha, & Sakai, 2023; Winters et al., 2022; Winters, Sakai, & Carter, 2021) as well as the ACC and amygdala and anterior insula (Winters & Hyde, 2022; Drew E Winters, Daniel Leopold, et al., 2023). Moreover, one study found aberrant ACC connectivity is implicated in cognitive controls influence with ToM (Drew E. Winters et al., 2023). Together, these findings support CU trait specific resource limitations that impact cognitive-affective processes and are, in part, supportive of cognitive-affective adult models (e.g., Baskin-Sommers et al., 2022; Baskin-Sommers & Newman, 2013).

However, to better evaluate cognitive-affective models in relation to CU traits and CP in youth, studies are needed that adopt dual-task designs, which offer advantages over pre-post-designs when studying cognition. Cognitive processes in humans such as response selection, attention, and cognitive load have been found to be constrained by limitations in central information processing and resources when tested with dual-tasks (Dux et al., 2006; Tombu et al., 2011). Dual-tasks (e.g., within trial increases of cognitive control demands to test effect on ToM) provide multiple advantages over pre-post designs (i.e., paradigm loading cognitive control with pre and post ToM) when testing central information processing that includes: (1) within trial tests that provide multiple datapoints providing a more reliable estimate; (2) within-subject concurrent performance that improves isolation of cognitive processes being tested; and

(3) the ability test different processes on primary task of interest in one task. Evidence of these advantages in neurotypical samples demonstrate reaction time changes after imposing a load between 0-500ms but not when delays are longer after the loading task (e.g., 1,100ms; Dux et al., 2006; Tombu et al., 2011). In a sample elevated in psychopathy, however, Tillem, Weinstein and Baskin-Sommers (2021) demonstrated that effects persisted from 300ms to at least 1,100ms indicating a greater difficulty recovering from additional load. Given prior work using a pre-post design implicates a similar effect in early adolescents (Winters & Sakai, 2023), using a dual-task design offers the ability to replicate and extend these prior findings.

Additional considerations to improve inferences on cognitive-affective interactions unique to CU traits involve design considerations of the dual-task, statistical controls, and sample recruitment. For study design, incorporating the recruitment of a control sample that does not receive the exposure, the use of a double-blind randomized clinical trial, and leveraging a ToM task that tests cognitive, affective, and physical conditions in order to isolate the separate components of ToM would improve inferences at the design level. For statistical controls, including ADHD, IQ, and internalizing to better isolate variance specific to CU and CP. For the sample, recruiting from the community as opposed to comparing incarcerated and nonincarcerated samples can improve estimates by affording (1) adequate sample variance to detect ToM and cognition effects that are commensurate with incarcerated samples (e.g., Andover et al., 2011; Gillespie et al., 2018; Viding & McCrory, 2012); (2) less unaccounted for bias being introduced (e.g., omitted variable bias: Wilms et al., 2021) due to non-random differences in chronic health conditions, demographic, and socioeconomic origins that known to differentiate incarcerated samples that impact health and cognition (e.g., Ahalt et al., 2012;

Massoglia, Firebaugh, & Warner, 2013); and (3) robust isolation of phenotypic associations due to less ceiling effects on trauma and confounding mental health domains (Wolff & Shi, 2012).

The present study builds on prior work by implementing the improvements listed above in a preregistered data collection and analysis (https://doi.org/10.17605/OSF.IO/BHWEU). This approach is leveraged to test the overarching hypothesis that those elevated in CU traits will demonstrate unique decrements in ToM during the dual-task. The preregistered hypotheses by ToM trial type for those elevated in CU traits are: H1) cognitive ToM trials will not change, H2) affective ToM will demonstrate a decrement, and H3) physical causality trials will not change. Testing these hypotheses is a critical step in this line of work that can improve our understanding of these phenotypes and refine treatment targets to redress youth antisocial behavior.

Methods

Power analyses

Two *a priori* power analyses were conducted for sample size determination. The first was based on Tillem, Weinstein and Baskin-Sommers (2021) adult dual-task findings testing cognitive performance association with psychopathy to determine the sample needed for an omnibus test comparing against controls using G*Power (Faul et al., 2009). A second power analysis simulated the proposed repeated measures mixed effects model 1000 times in simr (Green, MacLeod, & Alday, 2017). Simulations indicated a sample of 80 participants afforded at least 90% power to detect test effects across repeated measures for phenotypic specific effects and G*Power indicated a minimum of 72 participants was required for 80% power as an omnibus test. This motivated a recruitment goal of 100 participants to account for up to 20% attrition.

Recruitment

The study protocol, recruitment, and consents were approved by the Colorado Multiple Institutional Review Board. Following the procedures as our prior work (Winters & Sakai, 2023), participants were recruited via online ads. After the initial response, a responsible adult was required to verify their consent to the youth participating and the participants age as well as upload their non-expired government-issued identification. This safeguard was implemented to protect against confounds, such as repeat participants or multiple participants within a household (protecting against another in the home that already completed coaching or completing for the subject). Once consent and assent were obtained, participants were selected based on age (12-14), Intelligence Quotient (IQ) >70 as measured by the Shipley-2 (Zachary & Shipley, 1986), no indication of autism risk as measured by adult rated Autism Spectrum Screening Questionnaire with a score >= 13 indicating risk (Ehlers, Gillberg, & Wing, 1999), and predefined recruitment cells involving: equal distributions for sex at birth and CU trait severity (identified with the 9-item split coding of the Inventory of Callous and Unemotional Traits; Kimonis et al., 2015; Sakai et al., 2016). Participants meeting criteria were excluded if they did not receive the effect being studied as indicated by inhibitory processing task performance that was defined by (1) participant had no correct responses for at least one of each inhibitory processing task trial (indicating they did not know how to respond), and/or (2) the participant was both a high outlier for go trials and a low outlier for inhibition trials that was defined using the median ± 2*median absolute deviation (indicating the participant was not participating to receive the effects being tested), which is commensurate with other studies (e.g., Spunt et al., 2012; Winters & Sakai, 2023). Collection stopped when the study recruitment goal was achieved.

Study Procedure

Qualifying participants were randomized into treatment or control group and a counterbalanced ordering of tasks, to factor out any potential learning effects, that involved either single ToM task or dual-task first (see Randomization and Blinding). A single link affording one access to the behavioral paradigm created in PsychoPy (Peirce et al., 2019) and hosted in Pavlovia (https://pavlovia.org/) was provided that required a 5-digit code and participant email. Prior to accessing the paradigm, extensive instructions were given to the subject and responsible adult outlining requirements of (1) completion on a desktop or laptop computer alone, (2) internet access, and (3) uninterrupted time to complete the tasks. During the behavioral paradigm, participants first completed practice trials to understand the task prior to testing that involved 15 inhibitory processing trials, one single ToM trial, and one dual-task trial that involved 15 inhibitory processing trials and one ToM trial. The tested behavioral paradigm involved completion of a single ToM task and a dual-task that took < ~20 minutes to complete (see Dual-Task Paradigm Behavioral Tasks). Those assigned into the control condition were instructed to not inhibit their responses during the inhibitory processing component of the dual-task and to continue to press the spacebar regardless of the trial whereas those in the test condition were instructed to inhibit responses based on trial type (see Dual-Task Paradigm Behavioral Tasks). Trials within each task were randomly presented. Participants were reimbursed $10 for completion of the screening and $25 for completion of the paradigm for a total of $35 for completion of the study. No paradigm data was recorded for participants that did not complete the study.

Randomization and Blinding

A permuted block randomization stratified by sex at birth and severity of CU traits was conducted to assign participants to test and control groups. The order of task presentation was counterbalanced (single ToM vs. dual-task first) by alternating within each group to factor out learning effects in the final analysis. Assignment was double-blinded, meaning that study participants, investigators (D.E.W., J.T.S.), statisticians (D.E.W., S.K.M.), and research assistants (J.S.) that interacted with participants were blind to assignment. Two project coordinators were unblinded (C.N., K.R.) to monitor counterbalance and randomization.

Transparency and openness. The present study, collection, and analyses were preregistered prior to data collection (https://doi.org/10.17605/OSF.IO/BHWEU). The final analysis did not include self-reported pubertal development although it was preregistered as a confound for psychopathology onset (Graber, 2013) due to a collection technical error. Instead, internalizing was included due to its association with: (1) both social cognition (Konrad et al., 2024; Winters et al., 2021) and cognitive function (Blanken et al., 2017; Vedechkina, Bennett, & Holmes, 2023); (2) psychopathic trait expression (Kimonis et al., 2013; Todorov et al., 2024); (3) cognitive effects at low internalizing in psychopathy (Glass & Newman, 2009); and (4) pubertal processes being more closely linked than with age (Patton et al., 2007; Patton et al., 2008; Pfeifer & Allen, 2021). Age was not included because it has a latency of ~5 years in relation to pubertal onset (Parent et al., 2003) rendering age a less appropriate control as a pubertal proxy in a study targeting a sample with a restricted age spanning 2 years (see Table 1 demonstrating that demographic correlations are unrelated with age). All study data and code generating the task and statistical analysis as well as analysis output is available at https://osf.io/7g8cj/ and https://github.com/drewwint/pub_dual-task_tom_cog-ctrl_rct.

Sample

See Figure 1 for final sample numbers after removal for exclusion criteria. The final sample consisted of 85 adolescents (ages 12-14, 13±0.83) balanced on sex (female 47%, male

53%) with an IQ > 70 (IQ 94.84±17.02) and predominately White (White 67%, Asian 12%, Mixed Race 8%, Black 7%, Hispanic 5%, American Indian 1%). Clinically indicated proportions of the sample (identified via cut-offs for self-report measures) were: CU traits 48%, CP 18%, ADHD 26%, and internalizing symptoms 8%. Proportions of phenotype-specific clinical cutoffs by CU trait severity can be found in Supplementary Table 1. Sample demographic information and tests demonstrating no group differences in Table 1.

Self-Report Measures

The Inventory of Callous-Unemotional Traits (ICU; Frick, 2004; Sample Ω = 0.861). The 24-item ICU asks participants to rate items such as "I do not care who I hurt to get what I want" on a Likert scale from 0 ("not true at all") to 3 ("definitely true") with higher scores indicating higher CU traits. Consistent with previous research (Kimonis et al., 2015) we removed 2 items from the measure due to poor psychometrics prior to calculation of the total score used in analysis. During screening, we identified those elevated in CU traits using the 9-item split coding method (Kimonis et al., 2015; Sakai et al., 2016), which has shown the best reliability (0.72 versus the other methods 0.42 – 0.7; Kimonis et al., 2015) and remains consistent with prior work testing this effect (Winters & Sakai, 2023).

Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997; Goodman et al., 2003; total score sample Ω = 0.910). Conduct problems (Ω = 0.770), ADHD (Ω = 0.847), and internalizing (Ω = 0.779) symptoms were assessed using the 25-item SDQ. Participants rate items such as "I take things that are not mine from home, school or elsewhere" on a scale of 0 ("not True") to 2 ("Certainly True"). Higher scores indicate greater symptoms in that domain.

Delinquency Scale (Pechorro et al., 2019). Antisocial behavior was assessed with the Add Health Self-Report Delinquency Scale. This 17-item index of delinquent behavior assesses participant frequency of involvement in both violent and nonviolent acts. Participants rate items on a 4-point ordinal scale from 0 (none) to 3 (five or more times) on items such as ("get into a serious physical fight?") with higher scores indicating a greater participation in antisocial acts.

Shipley Institute of Living Scale-2 (Zachary & Shipley, 1986). This brief measure of IQ involves completion of 60-items with two subscales consisting of vocabulary and abstract thinking used to derive a metric indexing IQ.

Dual-Task Paradigm Behavioral Tasks

Stimulus Selective Stop Signal Task (SSSST; Sánchez-Carmona et al., 2021): The SSSST is a modified version of a stop signal task involving inhibition along with an added response selection during stop trials. The SSSST has three conditions involving the traditional go (60% of trials where participants press the spacebar when they see a single arrow down) and passive inhibit trials (20% of trials where participants don't press anything when they see a green square around the down arrow) along with a stop and select trial (20% of trials where participants press 'k' when they see a red diamond around the arrow). This additional trial type leverages principles of stimulus-driven attention (Corbetta & Shulman, 2002) for an active inhibitory response that is more desirable for the effect being tested because (1) passive only inhibitory trials are ineffective as a cognitive load during dual tasks (Van Nuland & Rogers, 2016) and (2) those elevated in CU traits show more consistent decrement in cognition that is specific to cognitive control when selectively inhibiting (e.g., Gluckman, Hawes, & Russell, 2016). The SSSST employs both response inhibition and selection components of cognitive control (Goghari & MacDonald III, 2009) that modulate ToM (Corbetta, Patel, & Shulman, 2008; Vetter et al., 2013; Wade et al., 2018) making it the ideal secondary task for the present dual-task paradigm (Task Schematic in Supplemental Figure 1-A).

Cognitive and Affective ToM Task CAToon (Borbás et al., 2021): CAToon consists of 30 hand-drawn stories, including two experimental conditions targeting affective ToM and cognitive ToM and physical causality as a control condition without cognitive or affective information. Each condition comprises 10 stories with different backgrounds for each story with similar visual complexity. The two experimental conditions were designed to differentially motivate affective versus cognitive aspects of ToM reasoning. During affective trials participants must infer how a character would react to a fellow character's expressed or expected emotions. During cognitive trials participants have to assume how characters would act based on another character's intentions or beliefs. Physical trials serve as a control condition, requiring a basic understanding of cause and effect and basic physical laws. Physical knowledge is implicated in theory of mind, but do not require inference of cognitive or affective states. All trials start with three consecutively presented images, followed by a single image displaying three possible endings from which to select (Task Schematic in Supplemental Figure 1-B).

Dual-task paradigm: The present dual-task design is based on testing cognitive load theory (Sweller, van Merrienboer, & Paas, 1998) grounded in evidence that there are independent subcomponents of cognition with limited capacity to handle multiple sources of information that can be tested using dual-task designs. This dual-task paradigm involves completing both the SSSST and the ToM task simultaneously with the SSSST as the secondary task that places additional demands on cognitive control (selective inhibition: Goghari & MacDonald III, 2009) that competes with ToM (Corbetta, Patel, & Shulman, 2008; Vetter et al., 2013; Wade et al., 2018). This dual-task design affords the test of cognitive controls processes involved in ToM.

This paradigm involves the completion of five SSSST trials (go 60%, passive inhibit 20%, and stop and select 20%) prior to each of the three scenes for each ToM trial. Because the dual-task was intended to increase load when inferring affective information and not deciding on the outcome of the trial, there were no SSSST trials before the ToM response and only before the three ToM scenes. Thus, 15 SSSST trials were completed for every one of the 30 ToM trials resulting in a total of 450 SSSST trials. Each trial (both SSSST and ToM) was presented randomly with each ToM scene presented for 1,100ms. The 1,100ms scene timing was chosen to minimize recovery time from load on cognitive control (impact up to 1,100ms for those elevated in psychopathic triats: Tillem, Weinstein, & Baskin-Sommers, 2021) while allowing adequate time to receive information from each ToM scene. The intertrial interval (ITI) had a jittered mean of 2000ms within 1500-2500ms to prevent patterned responses as well as spillover effects between trials (Task Schematic in Supplemental Figure 1-C).

Calculated Measures

Careless Respondents. To redress issues with inattentiveness or not responding to questionnaires in good faith, participants with highly patterned responses were identified using the 'careless' package (Yentes & Wilhelm, 2018). Specifically, a three-pronged approach identified 1) long-string – the length of same response with larger values indicating carelessness, 2) item-variability - how variable responses are with both extremely high [completely random] or low [consistent similarity] indicates carelessness, and 3) even-odd – similarity of even and odd item items with more similarity indicating carelessness (Dunn et al., 2018; Johnson, 2005). With these metrics, careless participants were defined with the median and highly conservative criteria of 3*median absolute deviation (Leys et al., 2013) to regress out spurious results due to carelessness.

Dual-Task Effects. In secondary analyses we tested a within-individual measure of change under the loaded dual-task relative to the single ToM task with the following equation

$\frac{(Dual\ Task - Single\ Task)}{Single\ Task}$ proposed by Longhurst et al. (2022). With this metric, higher scores indicate trials are easier to complete during the dual task whereas negative values indicate greater difficulty completing the trial during the dual-task.

Covariates

All analyses controlled for sex at birth, race, careless responses, ordering of tasks, ADHD, and internalizing symptoms. Race was included to account for variation in identifying emotions in those outside one's racial identity (Chiroro & Valentine, 1995). Race was dichotomized to represent the most represented racial category (White) because 1) ToM vignettes (although racially ambiguous) used a lighter skin tone for all actors that could be interpreted as an individual of European descent and 2) to have adequate representation of race by category to regress out race-related impact on ToM task. Careless responses were included to account for variation in participant inattentiveness to survey questions. Order of task presentation was included to regress out any learning effects despite randomized counterbalancing. ADHD is implicated in cognitive performance (Godinez et al., 2015; Longhurst et al., 2022) and often associated with externalizing behavior associated with CP and CU traits (Ahmad & Hinshaw, 2017). Finally, internalizing was included in our model to account for known impact on ToM (Konrad et al., 2024), and cognition (Blanken et al., 2017; Vedechkina, Bennett, & Holmes, 2023).

CU, CP, and ADHD were significantly related and were in our sample (Table 1). Thus, to ensure we retain adequate variance in CU and CP as our primary phenotypes of interest in our statistical models, we quantified the amount of variance left over using a modified multiple correlation coefficient formula by removing the square root that derives the correlation coefficient and with CU (x), CP (y), and ADHD (z): ${R^2}_{x*xy} = 1 - \frac{r_{xz}^2 + r_{yx}^2 - 2r_{xz}, r_{yx}, r_{xy}}{1 - r_{xy}^2} = 1 -$

$\frac{0.412+0.284-0.327}{0.774}$ = 0.52 or 52% of the variance in both CU traits and CP was retained. This is commensurate with other studies examining similar aged youth (e.g., Fontaine, Rozéfort, & Bégin, 2023; Saunders et al., 2019). Other potential confounds such as collider and suppression effects were not determined to impact model estimation given phenotypic associations are not caused by the exposure being tested (they were present prior to task) and no association with model residuals were found.

Analysis

Preliminary checks on randomization and variable normality. Participant characteristics were compared between groups using independent t tests and chi-square tests as appropriate to ensure randomization was successful. Quantitative variables were evaluated for approximate normality and associations among them at baseline were estimated with Pearson correlations.

Analytic approach. Using 'lme4' (Bates et al., 2014) and 'lmertest' (Kuznetsova, Brockhoff, & Christensen, 2019), repeated measures mixed effects modeling that accounted for individual random variation was used to test primary hypotheses on dual-task effects on ToM accuracy and reaction time as preregistered (https://doi.org/10.17605/OSF.IO/BHWEU) as well as secondary analyses. To test phenotypic implications in dual-task effects, interactions of time*group*phenotype (CU traits and CP) were derived using the residual centering approach (Geldhof et al., 2013; Little, Bovaird, & Widaman, 2006) that orthogonalizes interactions from the rest of the model, thus prevents violating modeling assumptions (i.e., correlated residuals) while removing any requirement to run multiple analyses on the same outcome. All model parameters were bootstrapped with 10,000 resamples using 'lmersample' (Loy & Korobova, 2021) to (1) test interaction effects, (2) adjust p values to correct for any bias along with

Satterthwaite's method (Satterthwaite, 1946) used with bootstrapped data, and (3) bolster confidence that sampling distribution did not distort model estimates. Importantly, p values were adjusted for multiple comparison with bootstrap corrected p values. We specifically used the non-parametric random effect block procedure for bootstrapping that improves reliability over parametric approaches due to loosening assumptions on residual normality and correlation structure of repeated measures and can redress violation of these assumptions if they exist (Chambers & Chandra, 2013). Overall, this approach bolsters our statistical inferences as we account for individual variation that overcomes many barriers of traditional analyses with repeated measures (e.g., ANOVA; Quené & van den Bergh, 2004), redresses missing variable bias (Ghose, 2019), and improves generalizability of results (Yarkoni, 2020).

Assumption Checking. In accordance with Antonakis, Bastardoz and Rönkkö (2021) on random effect modeling, we tested whether assumptions were met regarding endogeneity, heteroskedasticity, residual distribution, autocorrelation, and outliers that would influence results for all analyses using the 'performance' package (Lüdecke et al., 2021). There are no violations of these assumptions to report.

Results

No Sample or Initial Task Performance Abnormalities

Sample phenotype distribution commensurate with population norms and similar between groups. The current sample had distributions for the ICU (16.18±6.92) and SDQ CP (1.61±1.69), hyperactivity-inattention (4.14±2.87), and internalizing (5.33±3.70) that were within expected distributions for community samples in the sampled age range (Essau, Sasagawa, & Frick, 2006) and population norms (https://sdqinfo.org/norms/USNorm1.pdf). Importantly, the distribution of clinical cut-offs for these symptoms was not statistically different by group and order assignment (CU traits: X^2= 1.07, p=0.78; CP: X^2 = 2.37, p = 0.50; ADHD; X^2= 2.32, p= 0.51; Internalizing; X^2=5.94, p= 0.19; See Supplementary Figure 2).

Sample phenotype associations commensurate with broader literature. Phenotype associations demonstrated expected positive associations between CU traits, CP, ADHD, and internalizing (Table 1). There were expected phenotypic associations for CU traits and CP, with both related to higher delinquency and lower prosociality and mentalizing (Supplementary Figure 3).

No bias found in ToM or initial dual-task performance as expected. There was no detected baseline ToM ability bias as evidenced by no statistically meaningful differences in single ToM task performance by group assignment (F(3, 42.93)= 50, p= 0.68; Supplementary Figure 4). The dual-task performed as expected as evidenced by (1) the odds ratio (OR = 3.75) suggesting that test exposure reductions in ToM task performance is 3.75 times higher than those in the control condition and (2) participants in the control condition had statistically meaningful shorter reaction times than those in the test condition (T(46.52)= -21.67, p< 0.001; Supplementary Figure 5) suggesting participants and the cognitive load performed as expected.

CU Traits Uniquely Associate with Cognitive Control Limitations Impacting ToM

Overall ToM task *accuracy* and *reaction time* decrements specific to CU traits. Participants in the test group that were higher in CU traits had a distinct association with decrements in overall ToM task during the dual-task (relative to the single ToM task) for both accuracy (β = -8.05, p = 0.012, R^2= 0.192 [negative β indicates lower accuracy], Table 2, Figure 2A) and reaction time (β = 2.067, p = 0.185, R^2= 0.061 [positive β indicates longer reaction time], Table 3, Figure 3A).

Affective ToM *accuracy* and *reaction time* decrements specific to CU traits. Participants in the test group that were higher in CU traits had decrements in affective ToM accuracy (β= -5.477, p= 0.002, R^2= 0.165, Table 2, Figure 3B) and reaction time (β= 2.481, p= 0.007, R^2= 0.062, Table 3, Figure 2B) during the dual-task.

Cognitive ToM *accuracy* unaffected, but *reaction time* decrements specific to CU traits. Participants in the test group that were higher in CU traits associated with longer reaction times (β= 2.318, p = 0.020, R^2= 0.083, Table 3, Figure 3C), but no changes in cognitive ToM accuracy (β= -1.286, p = 0.416, R^2= 0.124, Table 2, Figure 2C) during the dual-task.

No changes detected in physical trials. Dual-task effects on physical trials had no statistically meaningful change from single to dual-task task (Tables 2-3).

CP ToM deficits are unrelated to cognitive control, but CU trait effects are dual-task specific. CP associated with ToM accuracy decrements during single ToM task (Supplemental tables 15-18) for baseline overall (β = -1.044, p = 0.021, R^2= 0.187) and baseline affective trials (β = -0.449, p = 0.022, R^2= 0.133); however, there were no statistically meaningful effects detected for those in the test group that were elevated in CP during the dual-task after manipulating inhibition. CU traits, on the other hand, were associated with pronounced decrements in ToM after manipulating inhibition (Tables 2-3, Figures 2-3).

CU traits uniquely associate with greater difficulty during dual-task. Greater difficulty during the dual-task was also specific to those in the test group that were elevated in CU traits (β= -0.885, p= 0.022, R^2= 0.178) as no dual-task effects were detected for test participants with higher CP (Table 4).

The Impact of Cognitive Control is Pronounced for Affective ToM for CU traits

Contrasts between ToM trials revealed that CU traits were associated with lower accuracy during Affective > Physical trials (β= -4.811, $p = 0.009$, R^2= 0.138) and Affective > Cognitive (β= -4.860, $p = 0.008$, R^2= 0.138) but not Cognitive > Physical trials. These effects were unique to CU traits and not found for CP (Table 4).

Cognitive Resilience Associated with Less Delinquency for CU traits

Resilience to inhibition manipulation during affective ToM trials (defined as no decrease in affective ToM from single to dual-task amongst those in the test group) was associated with lower delinquency for those elevated in CU traits (β= -1.168, $p = 0.037$, R^2= 0.338; Table 4, Figure 4).

Discussion

The current study was a double-blind clinical trial with a community sample of early adolescents oversampled for elevated CU traits and balanced between sex at birth. Findings support a cognitive-affective interaction implicated in antisocial behavior that is unique to CU traits. Adolescents elevated in CU traits demonstrate resource limitations in cognitive control that (1) impacted ToM and (2) related to their self-reported antisocial behavior. These results extend previous work by isolating cognitive control in a within-trial dual-task design that utilized control and test subjects in a randomized clinical trial while isolating components of ToM and implementing statistical controls for IQ and known confounding symptoms. This study adds to the mounting evidence that cognitive-affective interactions are important for the study of antisocial behavior, particularly pathways involving CU traits.

Callous-Unemotional Affective Theory of Mind Deficits Involve Cognitive Control

CU traits were uniquely associated with ToM decrements after manipulating cognitive control. CU traits were associated with decrements in ToM regarding the change from single ToM task baseline to the dual-task after manipulating cognitive control but not the single ToM trial itself. This finding is consistent with the notion that those elevated in CU traits can superficially appear to infer and understand emotional states of others (e.g., Rijnders et al., 2021), but that more consistent decrements are found when adding additional cognitive demands (review: Baskin-Sommers & Brazil, 2022). Additional demands in the form of complex emotions (because they require more cognitive resources to process: Yates, Ashwin, & Fox, 2010) have also shown ToM decrements uniquely associating with CU traits during a single task in prior work (Sharp et al., 2015; Winters & Sakai, 2023). While informative, these prior efforts involved a single task that could not isolate the specific cognitive processes implicated in ToM deficits (i.e., showing only that when affect was more complex, it was more difficult at higher CU traits). While the ToM task in the present study had some complex emotions, these have not been formalized as in the task used in prior work with adequate trials to detect these effects. This is a plausible explanation as to why single ToM trials did not associate with CU, but instead elevated cognitive demands and evidence CU related ToM decrements involving the change from the single task to the dual-task implicate limitations in cognitive control. This result replicates Winters and Sakai (2023) initial early adolescent findings and extends it to within-trial changes in both accuracy and processing speed when inferring other's affective state.

CU trait cognitive control limitations linked distinctly to affective processing in ToM. Affective ToM decrements unique to CU traits were observed for both accuracy and reaction time as well as contrasts of affective ToM over cognitive ToM and physical trials. Thus, our results suggests that CU traits are specifically associated with difficulties inferring affect rather than physical or spatial inferences, with cognitive control resource limitations. That is vulnerability to greater cognitive demands impact the propensity to take in affective information from others. This finding replicates prior work (Winters & Sakai, 2023) and may support adult psychopathy models proposed by Baskin-Sommers et al. (2022) implicating affect in cognitive function. Results also speak to the assertion of Baskin-Sommers and Brazil (2022) that cognitive resources are involved in affective processing. The current affective ToM finding may also be developmentally specific in early adolescents that later result in learned cognitive strategies proposed in the attention-bottleneck model for adults elevated in psychopathy (e.g., Baskin-Sommers & Brazil, 2022). In an attempt to conserve resources a serial processing strategy may be used as it appears to consume less resources initially, but it is shown to expend greater resources in the long-term (Fischer & Plessow, 2015). Such an approach may train one to limit the scope of attention that information is processes to counteract resource limitations throughout early development and become a learned strategy impacting cognitive-affective competition for brain resources (e.g., Pessoa, 2010). This interpretation is initially evidenced by the current finding that dual-task effects were differentially more relevant for those elevated in CU traits.

Cognitive ToM trials revealed a decrement in processing speed that did not impact accuracy. This finding supports Drayton, Santos and Baskin-Sommers (2018) findings that there is a limitation in automaticity for cognitive ToM that does not necessarily impact accuracy. The present study extends this to early adolescents and specific functions of cognitive control for those elevated in CU traits. Additionally, in the present study, CU traits were associated with stronger dual-task effects without impacting cognitive ToM, which further supports the notion that cognitive control is uniquely implicated in affect processing. Together these findings suggest that affective ToM impairments link with cognitive control is more profound at elevated CU traits and further evidence a mechanism unique to CU traits involving cognitive-affective interactions.

CP **Affective Theory of Mind Decrements Unrelated to Cognitive Control**

CP were unrelated to ToM changes from single to dual-task but were related to decrements during the single ToM task. Importantly, the trial-specific decrement during the single task for CP was specific to affective ToM trials. This finding is consistent with prior findings that CP associates with decrements in ToM (Holl, Vetter, & Elsner, 2021) and extends it by clarifying that cognitive control is not implicated in ToM in those elevated in CP. CP (precursor to the antisocial lifestyle features of adult psychopathy) is associated with stronger, pervasive, and profound cognitive impairments, which are thought to underpin risk impulsive antisocial acts (Baskin-Sommers et al., 2022). That is, there may be non-specific and pervasive cognitive impairments associated with CP are plausibly unrelated to understanding others affective and emotional state, but rather behavioral impulsivity implicated in delinquent acts. It may also be that there are floor effects on specific cognitive functions given the stronger relationships with cognitive impairments that make manipulation that tax cognitive control less effective for those elevated in CP. Thus, CP may be more related to difficulties in affective ToM at baseline because of pervasive cognitive limitations that are not specific to affect processing. This interpretation is consistent with conceptual definition of CP that can present without the affective deficits defining CU traits. The present results differentiate CU traits from CP in the specific cognition-affect interactions between cognitive control and affective ToM unrelated to CP are implicated in CU.

Cognitive Resilience Related to Less Delinquency for Callous-Unemotional Traits

In the finding regarding CU trait decrements in ToM during the dual task, secondary analysis found a subgroup of participants in the test group with little to no change in affective ToM that associated with lower delinquency. While not the primary focus of this study and only representing < ¼ of participants – this promising initial finding indicates that being resilient to impositions on cognitive control associate with lower real word antisocial behavior. This suggests ways to counteract the vulnerability on cognitive resources associated with CU traits and may have real world implications on antisocial outcome reduction.

Limitations

The present study must be interpreted under some limitations. First, the timing of secondary task to load the performance on the primary task (1,100ms) was decided a priori. While this decision was sound and based on prior literature, we are unable to identify timing between load and stimulus that may be phenotype-specific. Second, we were unable to include self-report puberty as preregistered due to a technical error during collection. Pubertal development is an important consideration for the study of CU as early pubertal development has been found to be associated with elevated CU traits (Drew E Winters, Daniel Leopold, et al., 2023). This may have been mitigated by including internalizing that has been shown to be closely tied pubertal onset (Patton et al., 2008; Pfeifer & Allen, 2021) given that age has an inconsistent link with puberty that is not a suitable proxy for the study of a limited age range < 5 years (Parent et al., 2003). Third, findings on those resilient to load was not the primary aim of the study and therefore based on only a small fraction (< ¼) of those in the test group. Fourth, the measure of CU traits has, in some samples, shown highly correlated residuals that are likely related to sample characteristics (Morales-Vives et al., 2019) suggesting some potential limitations in smaller samples; however, prior work has shown the ICU is most relevant for the prediction of aggression, CP, and serious crime (Ray, Pechorro, & Gonçalves, 2016) indicating it was most appropriate for the current study. Future studies could build on these results by using alternative multidimensional measures of callousness to see if we can reach the same conclusions and parse multicomponent features of psychopathy in relation to these results (Salekin, 2017). Fifth, this study was underpowered for nuanced interactions on primary and secondary variant interactions. While we controlled for internalizing symptoms that partially account for this, we acknowledge larger samples are needed to determine if there are mechanistically unique features specific to each variant for cognitive-affective interactions that are clinically relevant. Finally, the current sample included community adolescents that, as described above, provides adequate variance necessary to detect nuanced effects while also representing similar deficits as those who are incarcerated; however, results may not reflect the profound impairments of incarcerated or clinical samples.

Conclusions

In conclusion, the present double-blinded preregistered clinical trial supports a cognitive-affective interaction specific to CU traits during early adolescence, which implicated in real-world antisocial outcomes. Specifically, the small subsample resilient to cognitive demands reported less antisocial behavior and those that are less resilient to demands on cognitive control reported greater antisocial behavior. Preregistered hypotheses were mostly supported such that H2) affective ToM saw greater decrements in accuracy and processing speed unique to higher CU traits after manipulating cognitive control, and H3) physical trials saw no change. Cognitive ToM H1) hypothesis was partially supported in that accuracy did not change but we did find a decrement in processing speed after manipulating cognitive control. While not initially expected – this unexpected finding further adds to the notion that cognitive control limitations are pronounced and more vulnerable to demands amongst those elevated in CU traits but that affective processing during affective ToM is the primary domain of impact. Together these results support that cognitive-affective interactions are important for the study of CU and its development into adulthood that plausibly indicate an early risk in the development of cognitive and affective processing strategies represented in adult etiological perspectives on psychopathy. Thus, further work on the cognitive-affective decrements specific to CU traits in early adolescents involving resource limitations on cognitive control may facilitate new understanding of these traits and their development that can lead to more efficacious new interventions to redress persistent antisocial behavior.

References

Ahalt, C., Binswanger, I. A., Steinman, M., Tulsky, J., & Williams, B. A. (2012). Confined to ignorance: the absence of prisoner information from nationally representative health data sets. *Journal of general internal medicine*, *27*, 160-166.

Ahmad, S. I., & Hinshaw, S. P. (2017). Attention-deficit/hyperactivity disorder, trait impulsivity, and externalizing behavior in a longitudinal sample. *Journal of abnormal child psychology*, *45*(6), 1077-1089.

Andover, M. S., Schatten, H. T., Crossman, D. M., & Donovick, P. J. (2011). Neuropsychological functioning in prisoners with and without self-injurious behaviors: Implications for the criminal justice system. *Criminal Justice and Behavior*, *38*(11), 1103-1114.

Antonakis, J., Bastardoz, N., & Rönkkö, M. (2021). On ignoring the random effects assumption in multilevel models: Review, critique, and recommendations. *Organizational Research Methods*, *24*(2), 443-483.

Baskin-Sommers, A., & Brazil, I. A. (2022). The importance of an exaggerated attention bottleneck for understanding psychopathy. *Trends in cognitive sciences*, *26*(4), 325-336.

Baskin-Sommers, A., Ruiz, S., Sarcos, B., & Simmons, C. (2022). Cognitive–affective factors underlying disinhibitory disorders and legal implications. *Nature Reviews Psychology*, *1*(3), 145-160.

Baskin-Sommers, A. R., & Newman, J. P. (2013). Differentiating the cognition-emotion interactions that characterize psychopathy versus externalizing.

Baskin-Sommers, A. R., Waller, R., Fish, A. M., & Hyde, L. W. (2015). Callous-unemotional traits trajectories interact with earlier conduct problems and exec-utive control to predict violence and substance use among high risk male adolescents. *J Abnorm Child Psychol*, *43*(8), 1529-1541. https://doi.org/10.1007/s10802-015-0041-8

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *arXiv preprint arXiv:1406.5823*.

Blair, R. J., Leibenluft, E., & Pine, D. S. (2014). Conduct disorder and callous-unemotional traits in youth. *N Engl J Med*, *371*(23), 2207-2216. https://doi.org/10.1056/NEJMra1315612

Blair, R. J., & Mitchell, D. G. (2009). Psychopathy, attention and emotion. *Psychol Med*, *39*(4), 543-555. https://doi.org/10.1017/s0033291708003991

Blair, R. J. R. (2005). Applying a cognitive neuroscience perspective to the disorder of psychopathy. *Development and psychopathology*, *17*(3), 865-891.

Blanken, L. M., White, T., Mous, S. E., Basten, M., Muetzel, R. L., Jaddoe, V. W., Wals, M., van der Ende, J., Verhulst, F. C., & Tiemeier, H. (2017). Cognitive functioning in children with internalising, externalising and dysregulation problems: a population-based study. *European Child & Adolescent Psychiatry*, *26*, 445-456.

Borbás, R., Fehlbaum, L. V., Rudin, U., Stadler, C., & Raschle, N. M. (2021). Neural correlates of theory of mind in children and adults using CAToon: Introducing an open-source child-friendly neuroimaging task. *Developmental cognitive neuroscience*, *49*, 100959.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychol Rev*, *108*(3), 624-652. https://doi.org/10.1037/0033-295x.108.3.624

Brosch, T., Scherer, K., Grandjean, D., & Sander, D. (2013). The impact of emotion on perception, attention, memory, and decision-making. *Swiss medical weekly*, *143*(1920), w13786-w13786.

Chambers, R., & Chandra, H. (2013). A random effect block bootstrap for clustered data. *Journal of Computational and Graphical Statistics*, *22*(2), 452-470.

Chiroro, P., & Valentine, T. (1995). An Investigation of the Contact Hypothesis of the Own-race Bias in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *48*(4), 879-894. https://doi.org/10.1080/14640749508401421

Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: from environment to theory of mind. *Neuron*, *58*(3), 306-324.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*(3), 201-215. https://doi.org/10.1038/nrn755

Drayton, L. A., Santos, L. R., & Baskin-Sommers, A. (2018). Psychopaths fail to automatically take the perspective of others. *Proceedings of the National Academy of Sciences*, *115*(13), 3302-3307. https://doi.org/10.1073/pnas.1721903115

Duncan, S., & Barrett, L. F. (2007). Affect is a form of cognition: A neurobiological analysis. *Cognition and emotion*, *21*(6), 1184-1211.

Dunn, A. M., Heggestad, E. D., Shanock, L. R., & Theilgard, N. (2018). Intra-individual response variability as an indicator of insufficient effort responding: Comparison to other indicators and relationships with individual differences. *Journal of Business and Psychology*, *33*(1), 105-121.

Dux, P. E., Ivanoff, J., Asplund, C. L., & Marois, R. (2006). Isolation of a central bottleneck of information processing with time-resolved FMRI. *Neuron*, *52*(6), 1109-1120. https://doi.org/10.1016/j.neuron.2006.11.009

Ehlers, S., Gillberg, C., & Wing, L. (1999). A screening questionnaire for Asperger syndrome and other high-functioning autism spectrum disorders in school age children. *J Autism Dev Disord*, *29*(2), 129-141. https://doi.org/10.1023/a:1023040610384

Essau, C. A., Sasagawa, S., & Frick, P. J. (2006). Callous-unemotional traits in a community sample of adolescents. *Assessment*, *13*(4), 454-469.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149-1160. https://doi.org/10.3758/BRM.41.4.1149

Fischer, R., & Plessow, F. (2015). Efficient multitasking: Parallel versus serial processing of multiple tasks. *Frontiers in Psychology*, *6*, 1366.

Fontaine, N. M., Rozéfort, A., & Bégin, V. (2023). Associations between callous-unemotional traits and psychopathology in a sample of adolescent females. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, *32*(1), 14.

Foster, E. M., Jones, D. E., & Group, C. P. P. R. (2005). The high costs of aggression: Public expenditures resulting from conduct disorder. *American journal of public health*, *95*(10), 1767-1772.

Frick, P. J. (2004). The inventory of callous-unemotional traits. *Unpublished rating scale*.

Frick, P. J., & White, S. F. (2008). Research review: The importance of callous ‐ unemotional traits for developmental models of aggressive and antisocial behavior. *Journal of child psychology and psychiatry*, *49*(4), 359-375.

Gatner, D. T., Douglas, K. S., Almond, M. F., Hart, S. D., & Kropp, P. R. (2023). How much does that cost? Examining the economic costs of crime in North America attributable to

people with psychopathic personality disorder. *Personality Disorders: Theory, Research, and Treatment*, *14*(4), 391.
Geldhof, G. J., Pornprasertmanit, S., Schoemann, A. M., & Little, T. D. (2013). Orthogonalizing through residual centering: Extended applications and caveats. *Educational and psychological measurement*, *73*(1), 27-46.
Ghose, A. (2019). Problems of endogeneity in social science research. In *Research Methodology for Social Sciences* (pp. 218-252). Routledge India.
Gillespie, S. M., Kongerslev, M. T., Sharp, C., Bo, S., & Abu-Akel, A. M. (2018). Does affective theory of mind contribute to proactive aggression in boys with conduct problems and psychopathic tendencies? *Child Psychiatry & Human Development*, *49*(6), 906-916.
Gillespie, S. M., Lee, J., Williams, R., & Jones, A. (2022). Psychopathy and response inhibition: A meta-analysis of go/no-go and stop signal task performance. *Neuroscience & Biobehavioral Reviews*, 104868.
Glass, S. J., & Newman, J. P. (2009). Emotion processing in the criminal psychopath: the role of attention in emotion-facilitated memory. *J Abnorm Psychol*, *118*(1), 229.
Gluckman, N. S., Hawes, D. J., & Russell, A. M. T. (2016). Are Callous-Unemotional Traits Associated with Conflict Adaptation in Childhood? *Child Psychiatry & Human Development*, *47*(4), 583-592. https://doi.org/10.1007/s10578-015-0593-4
Godinez, D. A., Willcutt, E. G., Burgess, G. C., Depue, B. E., Andrews-Hanna, J. R., & Banich, M. T. (2015). Familial risk and ADHD-specific neural activity revealed by case-control, discordant twin pair design. *Psychiatry Research: Neuroimaging*, *233*(3), 458-465.
Goghari, V. M., & MacDonald III, A. W. (2009). The neural basis of cognitive control: Response selection and inhibition. *Brain Cogn*, *71*(2), 72-83.
Goodman, R. (1997). The Strengths and Difficulties Questionnaire: a research note. *Journal of child psychology and psychiatry*, *38*(5), 581-586.
Goodman, R., Ford, T., Simmons, H., Gatward, R., & Meltzer, H. (2003). Using the Strengths and Difficulties Questionnaire (SDQ) to screen for child psychiatric disorders in a community sample. *International Review of Psychiatry*, *15*(1-2), 166-172.
Graber, J. A. (2013). Pubertal timing and the development of psychopathology in adolescence and beyond. *Hormones and Behavior*, *64*(2), 262-269.
Green, P., MacLeod, C., & Alday, P. (2017). simr-power analysis for generalised linear mixed models by simulation. R package version 1.0. 3. In.
Holl, A. K., Vetter, N. C., & Elsner, B. (2021). Disentangling the relations of theory of mind, executive function and conduct problems. *Journal of applied developmental psychology*, *72*, 101233.
Imuta, K., Henry, J. D., Slaughter, V., Selcuk, B., & Ruffman, T. (2016). Theory of mind and prosocial behavior in childhood: A meta-analytic review. *Developmental psychology*, *52*(8), 1192.
Johnson, J. A. (2005). Ascertaining the validity of individual protocols from web-based personality inventories. *Journal of Research in Personality*, *39*(1), 103-129.
Kahn, R. E., Byrd, A. L., & Pardini, D. A. (2013). Callous-unemotional traits robustly predict future criminal offending in young men. *Law and Human Behavior*, *37*(2), 87-97. https://doi.org/10.1037/b0000003
Kimonis, E. R., Fanti, K. A., Frick, P. J., Moffitt, T. E., Essau, C., Bijttebier, P., & Marsee, M. A. (2015). Using self-reported callous-unemotional traits to cross-nationally assess the

DSM-5 'With Limited Prosocial Emotions' specifier. *Journal of child psychology and psychiatry*, *56*(11), 1249-1261. https://doi.org/10.1111/jcpp.12357

Kimonis, E. R., Fanti, K. A., Isoma, Z., & Donoghue, K. (2013). Maltreatment profiles among incarcerated boys with callous-unemotional traits. *Child Maltreat*, *18*(2), 108-121.

Konrad, A. C., Förster, K., Stretton, J., Dalgleish, T., Böckler‐Raettig, A., Trautwein, F. M., Singer, T., & Kanske, P. (2024). Risk factors for internalizing symptoms: The influence of empathy, theory of mind, and negative thinking processes. *Human Brain Mapping*, *45*(3), e26576.

Krishnan, A., Woo, C.-W., Chang, L. J., Ruzic, L., Gu, X., López-Solà, M., Jackson, P. L., Pujol, J., Fan, J., & Wager, T. D. (2016). Somatic and vicarious pain are represented by dissociable multivariate brain patterns. *elife*, *5*, e15166.

Kuznetsova, A., Brockhoff, P., & Christensen, R. (2019). Package 'lmertest'. Version 3.1-0.

Leys, C., Ley, C., Klein, O., Bernard, P., & Licata, L. (2013). Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. *Journal of Experimental Social Psychology*, *49*(4), 764-766.

Little, T. D., Bovaird, J. A., & Widaman, K. F. (2006). On the Merits of Orthogonalizing Powered and Product Terms: Implications for Modeling Interactions Among Latent Variables. *Structural Equation Modeling: A Multidisciplinary Journal*, *13*(4), 497-519. https://doi.org/10.1207/s15328007sem1304_1

Longhurst, J. K., Rider, J. V., Cummings, J. L., John, S. E., Poston, B., Held Bradford, E. C., & Landers, M. R. (2022). A novel way of measuring dual-task interference: the reliability and construct validity of the dual-task effect battery in neurodegenerative disease. *Neurorehabilitation and neural repair*, *36*(6), 346-359.

Loy, A., & Korobova, J. (2021). Bootstrapping Clustered Data in R using lmeresampler. *arXiv preprint arXiv:2106.06568*.

Lüdecke, D., Ben-Shachar, M. S., Patil, I., Waggoner, P., & Makowski, D. (2021). performance: An R package for assessment, comparison and testing of statistical models. *Journal of Open Source Software*, *6*(60).

Lykken, D. T. (2013). *The antisocial personalities*. Psychology Press.

Massoglia, M., Firebaugh, G., & Warner, C. (2013). Racial variation in the effect of incarceration on neighborhood attainment. *American sociological review*, *78*(1), 142-165.

Morales-Vives, F., Cosi, S., Lorenzo-Seva, U., & Vigil-Colet, A. (2019). The inventory of callous-unemotional traits and antisocial behavior (inca) for young people: Development and validation in a community sample. *Frontiers in Psychology*, *10*, 713.

Newman, J. P., & Lorenz, A. R. (2003). Response modulation and emotion processing: Implications for psychopathy and other dysregulatory psychopathology. *Handbook of affective sciences*, 904-929.

Parent, A.-S., Teilmann, G., Juul, A., Skakkebaek, N. E., Toppari, J., & Bourguignon, J.-P. (2003). The Timing of Normal Puberty and the Age Limits of Sexual Precocity: Variations around the World, Secular Trends, and Changes after Migration. *Endocrine Reviews*, *24*(5), 668-693. https://doi.org/10.1210/er.2002-0019

Patton, G. C., Hemphill, S. A., Beyers, J. M., Bond, L., Toumbourou, J. W., McMORRIS, B. J., & Catalano, R. F. (2007). Pubertal stage and deliberate self-harm in adolescents. *Journal of the American Academy of Child & Adolescent Psychiatry*, *46*(4), 508-514.

Patton, G. C., Olsson, C., Bond, L., Toumbourou, J. W., Carlin, J. B., Hemphill, S. A., & Catalano, R. F. (2008). Predicting female depression across puberty: a two-nation longitudinal study. *Journal of the American Academy of Child & Adolescent Psychiatry*, *47*(12), 1424-1432.

Pechorro, P., Moreira, K., Basto-Pereira, M., Oliveira, J. P., & Ray, J. V. (2019). The self-report delinquency scale from the national longitudinal study of adolescent to adult health among at-risk for delinquency youths. *Violence and victims*, *34*(1), 120-135.

Peirce, J., Gray, J. R., Simpson, S., MacAskill, M., Höchenberger, R., Sogo, H., Kastman, E., & Lindeløv, J. K. (2019). PsychoPy2: Experiments in behavior made easy. *Behavior Research Methods*, *51*, 195-203.

Perlstein, S., Fair, M., Hong, E., & Waller, R. (2023). Treatment of childhood disruptive behavior disorders and callous‐unemotional traits: A systematic review and two multilevel meta‐analyses. *Journal of child psychology and psychiatry*, *64*(9), 1372-1387.

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature Reviews Neuroscience*, *9*(2), 148-158.

Pessoa, L. (2010). Emergent processes in cognitive-emotional interactions. *Dialogues in Clinical Neuroscience*, *12*(4), 433-448.

Pfeifer, J. H., & Allen, N. B. (2021). Puberty initiates cascading relationships between neurodevelopmental, social, and internalizing processes across adolescence. *Biological Psychiatry*, *89*(2), 99-108.

Quené, H., & van den Bergh, H. (2004). On multi-level modeling of data from repeated measures designs: a tutorial. *Speech Communication*, *43*(1), 103-121. https://doi.org/https://doi.org/10.1016/j.specom.2004.02.004

Ray, J. V., Pechorro, P., & Gonçalves, R. A. (2016). A comparison of self-report measures of callous-unemotional traits among incarcerated youth: Associations with aggression, conduct disorder, and offending behavior. *Criminal Justice and Behavior*, *43*(10), 1293-1309.

Rijnders, R. J., Terburg, D., Bos, P. A., Kempes, M. M., & van Honk, J. (2021). Unzipping empathy in psychopathy: Empathy and facial affect processing in psychopaths. *Neuroscience & Biobehavioral Reviews*.

Rivenbark, J. G., Odgers, C. L., Caspi, A., Harrington, H., Hogan, S., Houts, R. M., Poulton, R., & Moffitt, T. E. (2018). The high societal costs of childhood conduct problems: evidence from administrative records up to age 38 in a longitudinal birth cohort. *Journal of child psychology and psychiatry*, *59*(6), 703-710.

Sakai, J. T., Mikulich-Gilbertson, S. K., Young, S. E., Rhee, S. H., McWilliams, S. K., Dunn, R., Salomonsen-Sautel, S., Thurstone, C., & Hopfer, C. J. (2016). Adolescent Male Conduct-Disordered Patients in Substance Use Disorder Treatment: Examining the "Limited Prosocial Emotions" Specifier. *Journal of Child & Adolescent Substance Abuse*, *25*(6), 613-625. https://doi.org/10.1080/1067828X.2016.1175983

Sakki, H., St Clair, M., Hwang, S., & Allen, J. L. (2023). The association between callous-unemotional traits and substance use in childhood and adolescence: A systematic review and meta-analysis. *J Affect Disord*.

Salekin, R. T. (2017). Research review: What do we know about psychopathic traits in children? *Journal of child psychology and psychiatry*, *58*(11), 1180-1200.

Sánchez-Carmona, A. J., Rincón-Pérez, I., López-Martín, S., Albert, J., & Hinojosa, J. A. (2021). The effects of discrimination on the adoption of different strategies in selective stopping. *Psychonomic Bulletin & Review*, *28*, 209-218.

Satterthwaite, F. E. (1946). An approximate distribution of estimates of variance components. *Biometrics bulletin*, *2*(6), 110-114.

Saunders, M. C., Anckarsäter, H., Lundström, S., Hellner, C., Lichtenstein, P., & Fontaine, N. M. (2019). The associations between callous-unemotional traits and symptoms of conduct problems, hyperactivity and emotional problems: A study of adolescent twins screened for neurodevelopmental problems. *Journal of abnormal child psychology*, *47*, 447-457.

Shamay-Tsoory, S. G., Harari, H., Aharon-Peretz, J., & Levkovitz, Y. (2010). The role of the orbitofrontal cortex in affective theory of mind deficits in criminal offenders with psychopathic tendencies. *Cortex*, *46*(5), 668-677.

Sharp, C., Vanwoerden, S., Van Baardewijk, Y., Tackett, J., & Stegge, H. (2015). Callous-unemotional traits are associated with deficits in recognizing complex emotions in preadolescent children. *Journal of personality disorders*, *29*(3), 347-359.

Shenhav, A., Botvinick, M. M., & Cohen, J. D. (2013). The expected value of control: an integrative theory of anterior cingulate cortex function. *Neuron*, *79*(2), 217-240.

Song, J.-H., Waller, R., Hyde, L. W., & Olson, S. L. (2016). Early callous-unemotional behavior, theory-of-mind, and a fearful/inhibited temperament predict externalizing problems in middle and late childhood. *Journal of abnormal child psychology*, *44*(6), 1205-1215.

Song, Z., Jones, A., Corcoran, R., Daly, N., Abu-Akel, A., & Gillespie, S. M. (2023). Psychopathic traits and theory of mind task performance: A systematic review and meta-analysis. *Neuroscience & Biobehavioral Reviews*, 105231.

Spunt, R. P., Lieberman, M. D., Cohen, J. R., & Eisenberger, N. I. (2012). The phenomenology of error processing: the dorsal ACC response to stop-signal errors tracks reports of negative affect. *Journal of cognitive neuroscience*, *24*(8), 1753-1765.

Sweller, J., van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive Architecture and Instructional Design. *Educational Psychology Review*, *10*(3), 251-296. https://doi.org/10.1023/A:1022193728205

Tillem, S., Weinstein, H., & Baskin-Sommers, A. (2021). Psychopathy is associated with an exaggerated attention bottleneck: EEG and behavioral evidence from a dual-task paradigm. *Cogn Affect Behav Neurosci*, *21*(4), 881-893. https://doi.org/10.3758/s13415-021-00891-z

Todorov, J. J., Kohls, G., Pauli, R., Rogers, J., Bernhard, A., Ackermann, K., Raschle, N. M., Dugre, J. R., Fernandez‐Rivas, A., & Gonzalez‐Torres, M. A. (2024). Maltreatment and parenting in youth with primary and secondary callous‐unemotional traits: Anxiety matters. *JCPP Advances*, e12266.

Tombu, M. N., Asplund, C. L., Dux, P. E., Godwin, D., Martin, J. W., & Marois, R. (2011). A Unified attentional bottleneck in the human brain. *Proceedings of the National Academy of Sciences*, *108*(33), 13426-13431. https://doi.org/doi:10.1073/pnas.1103583108

Van Nuland, S. E., & Rogers, K. A. (2016). E‐learning, dual‐task, and cognitive load: The anatomy of a failed experiment. *Anatomical Sciences Education*, *9*(2), 186-196.

Vedechkina, M., Bennett, M., & Holmes, J. (2023). Dimensions of internalizing symptoms are stable across early adolescence and predicted by executive functions: Longitudinal findings from the Adolescent Brain and Cognitive Development (ABCD) study. *Development and psychopathology*, 1-10.

Vetter, N. C., Altgassen, M., Phillips, L., Mahy, C. E., & Kliegel, M. (2013). Development of affective theory of mind across adolescence: disentangling the role of executive

functions. *Dev Neuropsychol*, *38*(2), 114-125. https://doi.org/10.1080/87565641.2012.733786
Viding, E., & McCrory, E. J. (2012). Genetic and neurocognitive contributions to the development of psychopathy. *Dev Psychopathol*, *24*(3), 969-983. https://doi.org/10.1017/s095457941200048x
Wade, M., Prime, H., Jenkins, J. M., Yeates, K. O., Williams, T., & Lee, K. (2018). On the relation between theory of mind and executive functioning: A developmental cognitive neuroscience perspective. *Psychonomic Bulletin & Review*, *25*(6), 2119-2140.
Waller, R., & Wagner, N. (2019). The Sensitivity to Threat and Affiliative Reward (STAR) model and the development of callous-unemotional traits. *Neuroscience & Biobehavioral Reviews*, *107*, 656-671.
White, B. A., Dede, B., Heilman, M., Revilla, R., Lochman, J., Hudac, C. M., Bui, C., & White, S. W. (2022). Facial affect sensitivity training for young children with emerging CU traits: An experimental therapeutics approach. *Journal of Clinical Child & Adolescent Psychology*, 1-13.
Wilms, R., Mäthner, E., Winnen, L., & Lanwehr, R. (2021). Omitted variable bias: A threat to estimating causal relationships. *Methods in Psychology*, *5*, 100075.
Winters, D. E., Brandon-Friedman, R., Yepes, G., & Hinckley, J. D. (2020). Systematic review and meta-analysis of socio-cognitive and socio-affective processes association with adolescent substance use. *Drug and Alcohol Dependence*, 108479. https://doi.org/10.1016/j.drugalcdep.2020.108479
Winters, D. E., Dugré, J. R., Sakai, J. T., & Carter, R. M. (2023). Executive function and underlying brain network distinctions for callous-unemotional traits and conduct problems in adolescents. *bioRxiv*.
Winters, D. E., Guha, A., & Sakai, J. T. (2023). Connectome-based predictive modeling of empathy in adolescents with and without the low-prosocial emotion specifier. *Neuroscience Letters*, *812*, 137371.
Winters, D. E., & Hyde, L. W. (2022). Associated functional network connectivity between callous-unemotionality and cognitive and affective empathy. *J Affect Disord*. https://doi.org/https://doi.org/10.1016/j.jad.2022.08.103
Winters, D. E., Leopold, D., Sakai, J., & Carter, R. M. (2023). Efficiency of heterogenous functional connectomes explains variance in callous-unemotional traits after computational lesioning of cortical midline and salience regions. *Brain connectivity*(ja).
Winters, D. E., Leopold, D. R., Carter, R. M., & Sakai, J. T. (2023). Resting-state connectivity underlying cognitive control's association with perspective taking in callous-unemotional traits. *Psychiatry Research: Neuroimaging*, *331*. https://doi.org/10.1016/j.pscychresns.2023.111615
Winters, D. E., Pruitt, P., Damoiseaux, J., & Sakai, J. T. (2022). Callous-unemotional traits in adolescents moderate neural network associations with empathy. *Psychiatry Research: Neuroimaging*, *320*, 111429. https://doi.org/https://doi.org/10.1016/j.pscychresns.2021.111429
Winters, D. E., Pruitt, P. J., Gambin, M., Fukui, S., Cyders, M. A., Pierce, B. J., Lay, K., & Damoiseaux, J. S. (2021). Cognitive and Affective Empathy as Indirect Paths Between Heterogeneous Depression Symptoms on Default Mode and Salience Network Connectivity in Adolescents. *Child Psychiatry & Human Development*. https://doi.org/10.1007/s10578-021-01242-2

Winters, D. E., & Sakai, J. T. (2023). Affective theory of mind impairments underlying callous-unemotional traits and the role of cognitive control. *Cognition and emotion*, 1-18.
Winters, D. E., Sakai, J. T., & Carter, M. R. (2021). Resting-state network topology characterizing callous-unemotional traits in adolescence. *NeuroImage: Clinical*, *32*, 102878. https://doi.org/https://doi.org/10.1016/j.nicl.2021.102878
Wolff, N., & Shi, J. (2012). Childhood and adult trauma experiences of incarcerated persons and their relationship to adult behavioral health problems and treatment. *International Journal Of Environmental Research And Public Health*, *9*(5), 1908-1926. https://doi.org/10.3390/ijerph9051908
Yarkoni, T. (2020). The generalizability crisis. *Behavioral and brain sciences*, 1-37. https://doi.org/10.1017/S0140525X20001685
Yates, A., Ashwin, C., & Fox, E. (2010). Does emotion processing require attention? The effects of fear conditioning and perceptual load. *Emotion (Washington, D.C.)*, *10*(6), 822-830. https://doi.org/10.1037/a0020325
Yentes, R. D., & Wilhelm, F. (2018). careless: Procedures for computing indices of careless responding. *R packages version 1.2.0*, *https://github.com/ryentes/careless*.
Zachary, R. A., & Shipley, W. C. (1986). *Shipley institute of living scale: Revised manual*. WPS, Western Psychological Services.

Table 1. Sample Descriptives

		Descriptives				Correlation Table							
			Group										
		Sample	Control	Test	t or X^2								
		Mean±SD or N(%)	Mean±SD or N(%)		p	2	3	4	5	6	7	8	9
1	CU traits	16.18±6.92	16.93±7.49	15.17±6.06	0.232	0.476*	0.034	-0.013	-0.064	0.034	0.022	0.533*	0.367
2	CP	1.61±1.69	1.55±1.72	1.69±1.68	0.333		-0.154	-0.069	-0.056	0.025	0.084	0.645*	0.470*
3	Sex (Male)				0.846			-0.056	0.106	0.092	-0.115	-0.074	-0.300
	Male	45(53%)	25(29%)	20(24%)									
	Female	40(47%)	24(28%)	16(19%)									
4	Race (White)				0.765				-0.023	-0.173	-0.129	0.033	-0.213
	White	57(67%)	34(40%)	23(27%)									
	Non-White	28(33%)	15(18%)	13(15%)									
5	IQ	94.84±17.02	92.1±14.6	98.5±19.4	0.101					0.000	0.025	-0.116	0.132
6	Age	13.04±0.84	13.02±0.82	13.05±0.86	0.851						-0.090	-0.035	0.059
7	Response	0.18±0.38	0.16±0.37	0.19±0.40	0.717							-0.001	0.081
8	ADHD	4.14±2.87	3.87±2.74	4.5±3.02	0.333								0.459*
9	Internalizing	5.33±3.70	4.65±3.43	6.25±3.90	0.060								

Table 2. ToM *Accuracy* Change from Single-Task to Dual-Task

Interactions[+]	β	se	t	p	Bootstrapped CI 95% Lower	Bootstrapped CI 95% Upper
***Overall* ToM** ~ (R^2= 0.192)						
CU	-8.050*	3.332	-2.575	0.012	-14.600	-1.553
CP	-4.510	6.188	-0.776	0.440	-16.500	7.716
***Affective* ToM** ~ (R^2= 0.165)						
CU	-5.475*	1.852	-3.142	0.002	-9.099	-1.836
CP	-3.068	3.423	-0.947	0.346	-9.689	3.686
***Cognitive* ToM** ~ (R^2= 0.124)						
CU	-1.286	1.697	-0.818	0.416	-4.556	2.048
CP	0.034	3.122	0.011	0.992	-6.129	6.088
Physical Trials ~ (R^2= 0.206)						
CU	-1.287	1.720	-0.801	0.425	-4.649	2.133
CP	-1.474	3.196	-0.492	0.624	-7.686	4.917

Notes: (1) Tables only show effects of interest involving interactions with group (test vs control) by repeated measures (single to dual-task) and phenotype (CU and CP). Full tables can be found in Supplemental Material (Supplemental Tables 2-5); (2) Parameters are bootstrapped corrected using 10,000 resamples

[+] = all levels of interaction were tested in the model, but only the tested interactions are listed.

* = statistically significant ($p < 0.05$) for two-tailed test with bootstrapped corrected p-values

Table 3. ToM *Reaction Time* Change from Single-Task to Dual-Task

Interactions+	β	se	t	p	Bootstrapped CI 95% Lower	Bootstrapped CI 95% Upper
***Overall* ToM** ~ (R^2= 0. 061)						
CU	2.067*	0.922	2.404	0.019	0.276	3.914
CP	2.226	1.725	1.392	0.168	-1.166	5.528
***Affective* ToM** ~ (R^2= 0. 062)						
CU	2.483*	0.970	2.736	0.008	0.583	4.417
CP	2.192	1.820	1.300	0.197	-1.433	5.758
***Cognitive* ToM** ~ (R^2= 0.083)						
CU	2.318*	1.058	2.369	0.020	0.245	4.442
CP	2.600	1.966	1.429	0.157	-1.312	6.453
Physical Trials ~ (R^2= 0.066)						
CU	1.402	0.979	1.518	0.133	-0.496	3.311
CP	1.890	1.840	1.099	0.275	-1.741	5.463

Notes: (1) Tables only show effects of interest involving interactions with group (test vs control) by repeated measures (single to dual-task) and phenotype (CU and CP) and complete tables can be found in Supplemental Material (Supplemental Tables 6-9); (2) Parameters are bootstrapped corrected using 10,000 resamples

+ = all levels of interaction were tested in the full model, but the tested interactions are listed.

* = statistically significant ($p< 0.05$) for two-tailed test with bootstrapped corrected p-values

Table 4. Secondary analyses

Interactions+	β	se	t	p	Bootstrapped CI 95% Lower	Upper
Dual-Task Effects from Single to Dual-Task						
Dual-Task Effects ~ (R^2= 0.223)						
CU	-0.885*	0.377	-2.345	0.022	-1.584	-0.207
CP	-0.273	0.155	-1.767	0.082	-0.558	0.007
Contrast Change from Single-Task to Dual-Task						
Affective > Physical ~ (R^2= 0.119)						
CU	-4.812*	1.935	-2.663	0.009	-8.573	-0.972
CP	-2.309	3.544	-0.688	0.494	-9.197	4.643
Cognitive > Physical ~ (R^2= 0.095)						
CU	-0.543	1.949	-0.302	0.763	-4.339	3.327
CP	0.887	3.595	0.264	0.792	-6.230	7.946
Affective > Cognitive ~ (R^2= 0.136)						
CU	-4.858*	1.922	-2.694	0.009	-8.593	-1.126
CP	-3.085	3.565	-0.920	0.360	-10.050	3.873
Delinquency as a function of Affective ToM Change from Single to Dual-Task						
Delinquency ~ Resilience to Load+++ ~ (R^2= 0.338)						
CU	-1.168*	0.549	-2.129	0.037	-2.126	-0.210
CP	0.286	0.151	1.899	0.062	-0.023	0.550

Notes: (1) Tables only show effects of interest involving interactions with group (test vs control) by repeated measures (single to dual-task) and phenotype (CU and CP) and complete tables can be found in Supplemental Material (Supplemental Tables 10-14); (2) Parameters are bootstrapped corrected using 10,000 resamples; (3) for dual-task effects negative values indicate greater difficulty for the dual-task (greater dual-task effect).

+ = all levels of interaction were tested in the full model, but the tested interactions are listed.

+++ = interactions include phenotype listed * Group * change after load

* = statistically significant (p< 0.05) for two-tailed test with bootstrapped corrected p-values

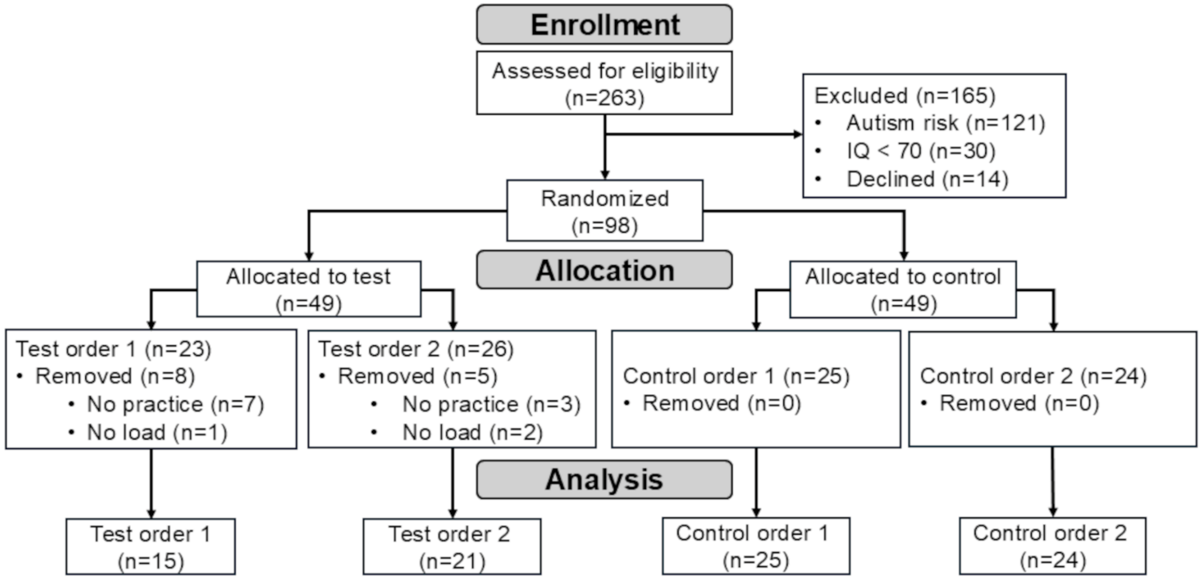


Figure 1. Consort flow diagram

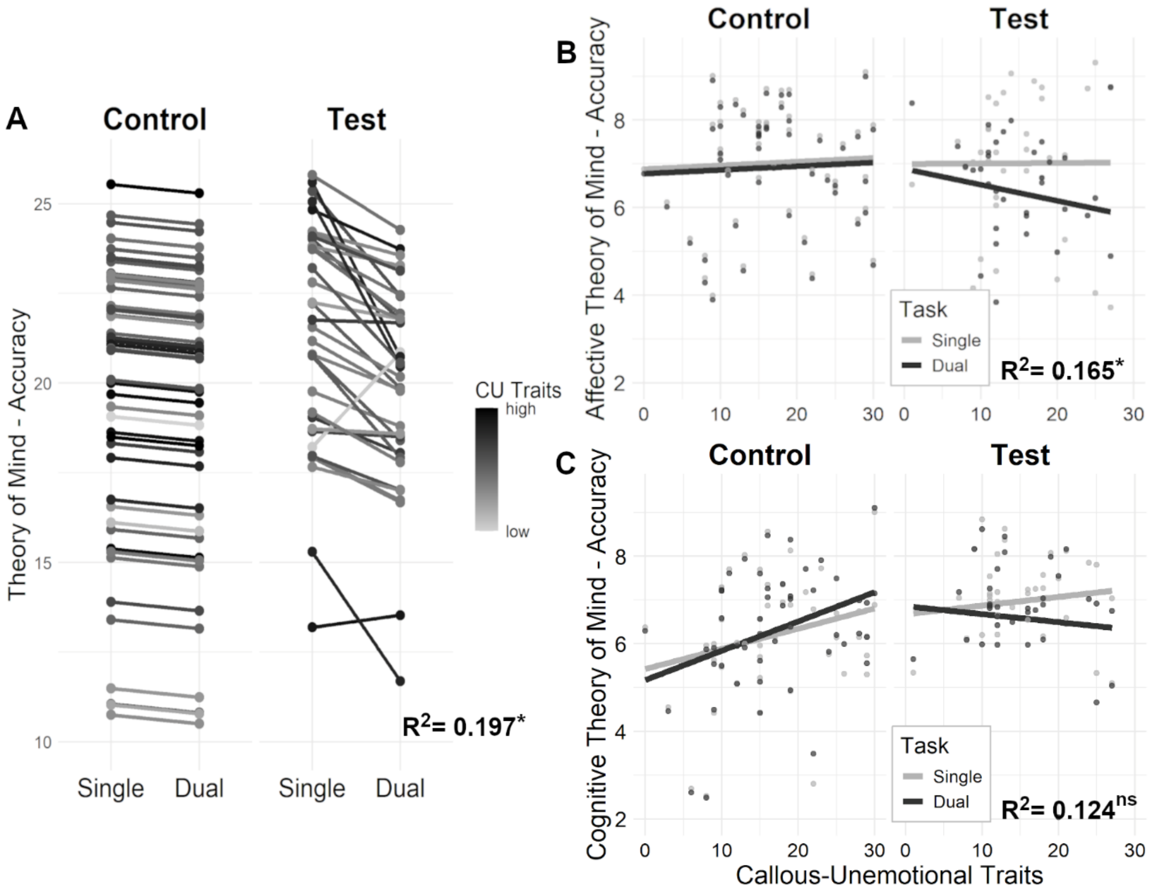


Figure 2. Depicting callous-unemotional traits association with theory of mind accuracy across repeated measures for control and test groups. A) overall task, B) Affective Trials, C) Cognition Trials.

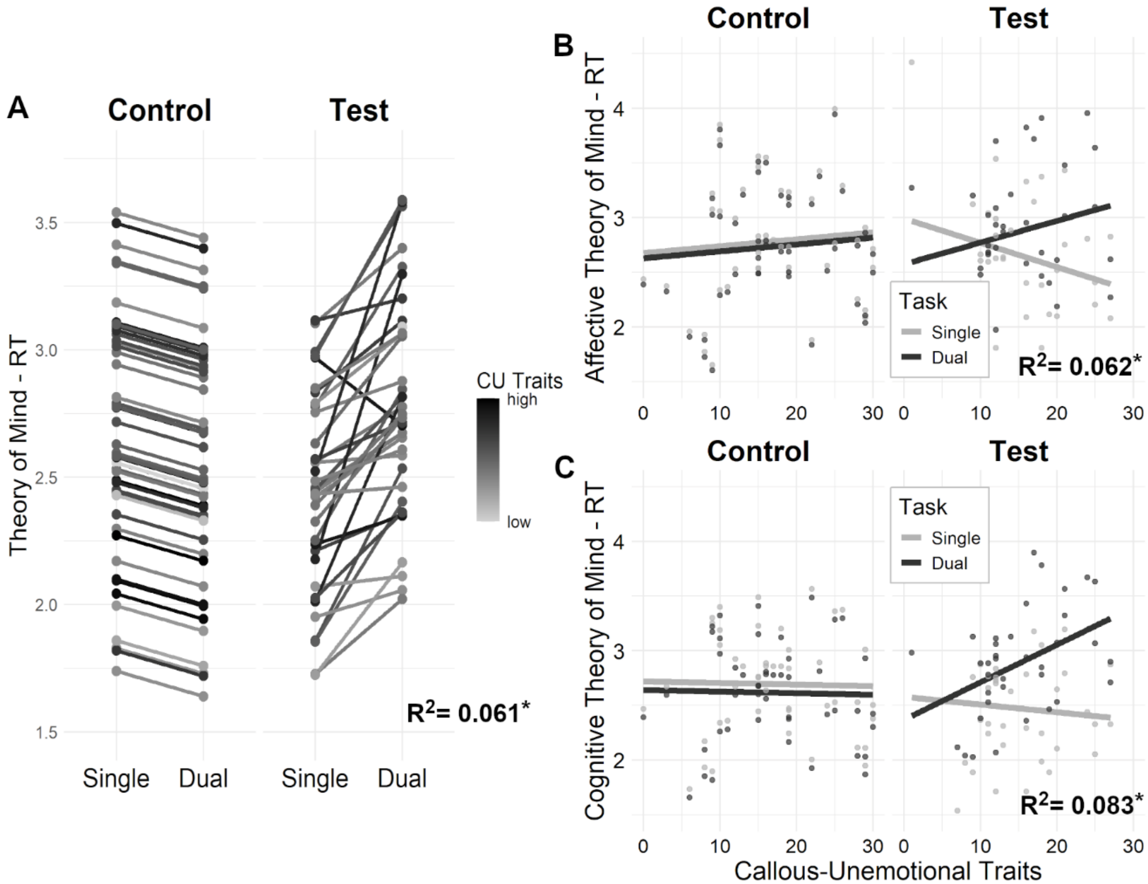


Figure 3. Depicting callous-unemotional traits association with theory of mind reaction time across repeated measures for control and test groups. A) overall task, B) Affective Trials, C) Cognition Trials.

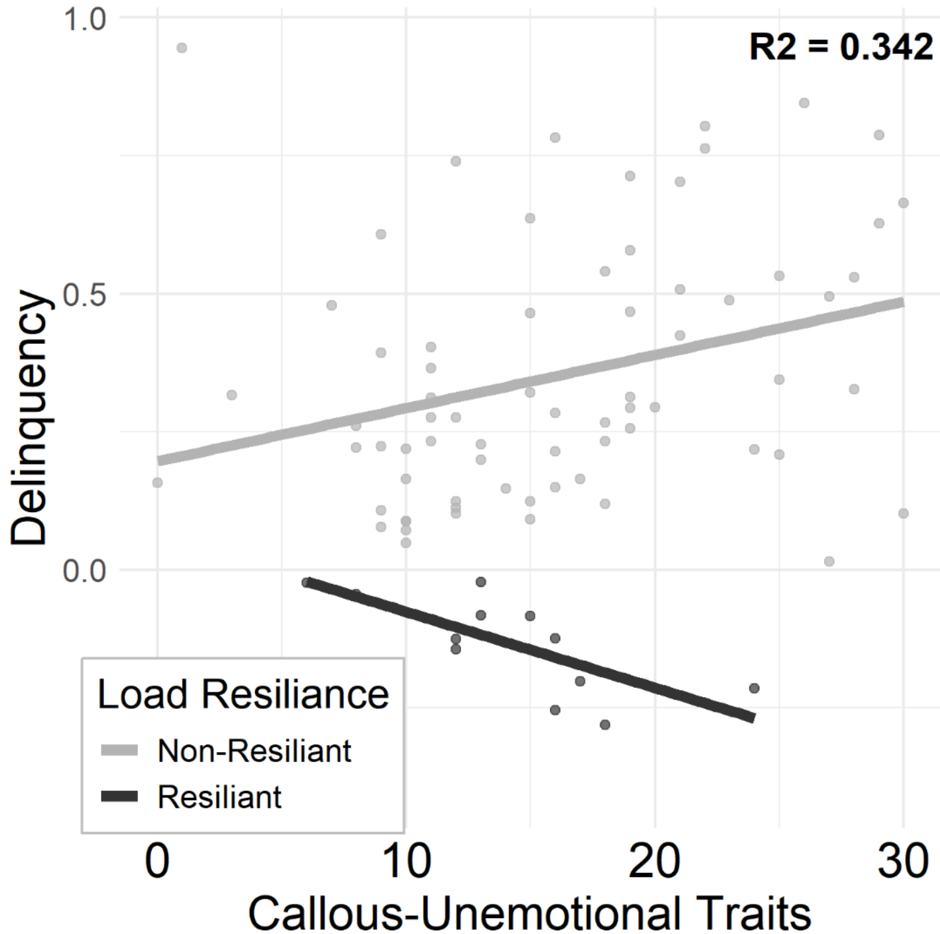


Figure 4. Depicting the relationship between delinquency and callous-unemotional traits for those non-resilient and resilient to cognitive load. Note: delinquency was log transformed due to the nature of being a count measure.

Supplemental Methods

Additional Correlation Measures in Supplemental Figure 3.

Measure of Prosociality: Prosociality was assessed using the strengths and difficulties questionnaire (Goodman, 1997). This 25-item measure has a 5-item subscale that assesses prosociality that was used in the supplemental correlation table. Participants rate items on a scale of 0 (“not True”) to 2 (“Certainly True”). Higher scores indicate greater prosociality.

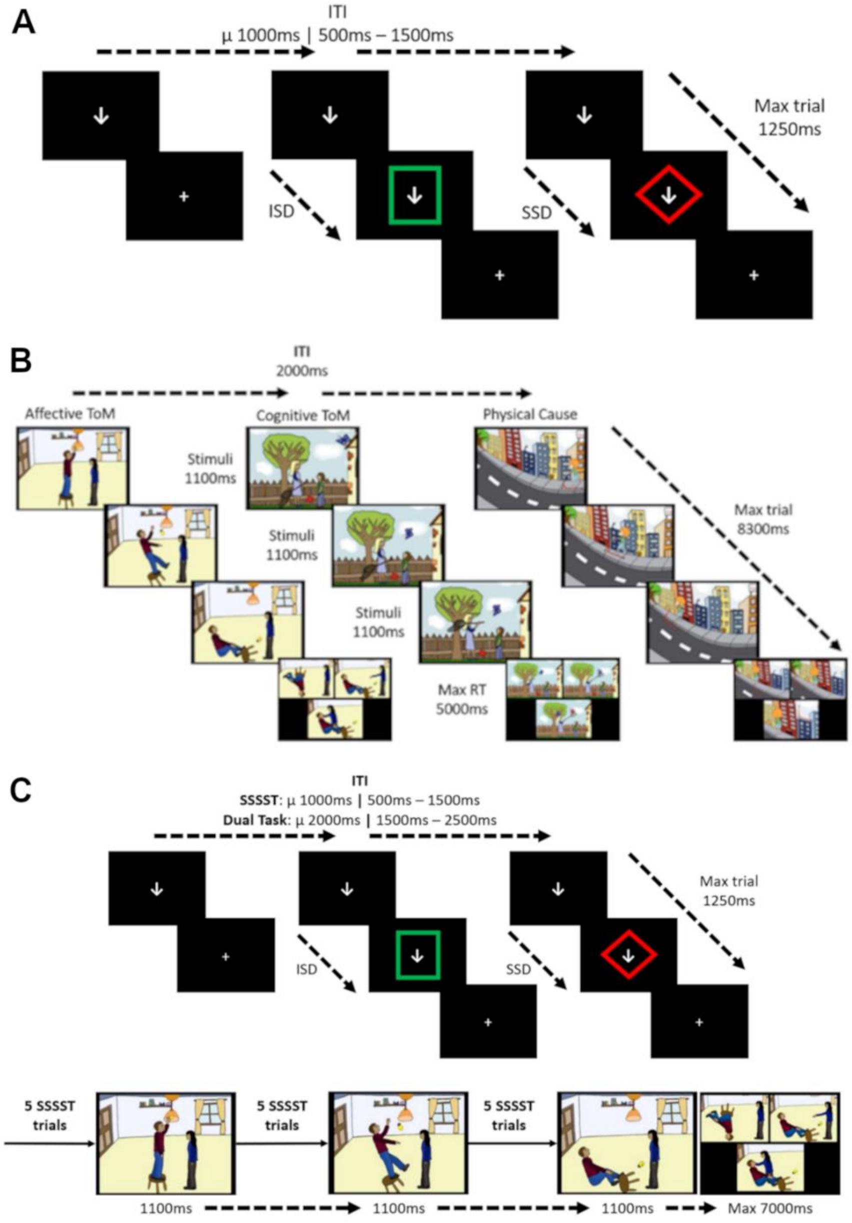
Measure of Mentalizing: To measure mentalizing we used the self-reflective functioning scale youth version (Duval et al., 2018). This is a 5-item version of the scale that assesses how youth reflectively think about others, their intentions, and their motives. Higher scores indicate greater mentalizing.

References

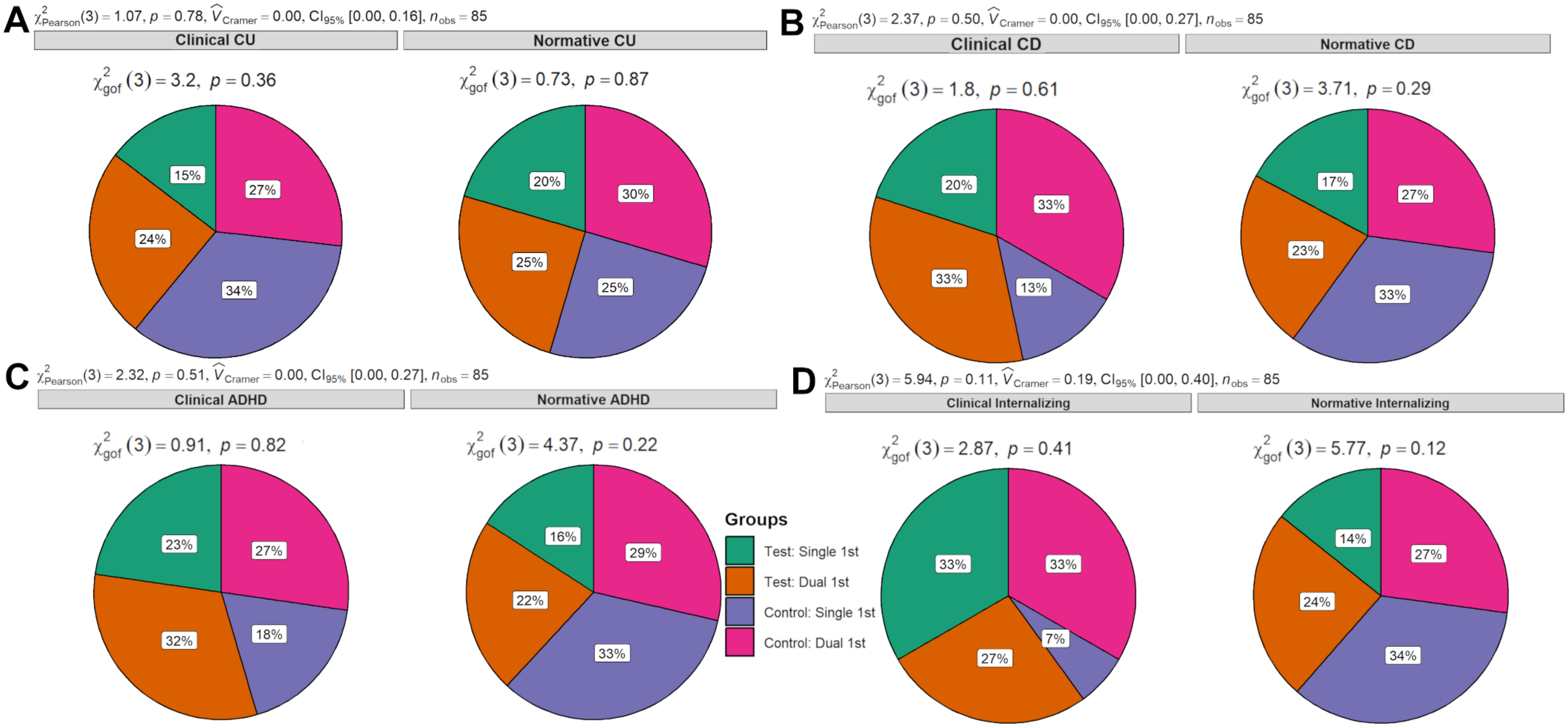
Duval, J., Ensink, K., Normandin, L., Sharp, C., & Fonagy, P. (2018). Measuring reflective functioning in adolescents: relations to personality disorders and psychological difficulties. Adolescent Psychiatry, 8(1), 5-20.

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: a research note. J Child Psychol Psychiatry, 38(5), 581-586. https://doi.org/10.1111/j.1469-7610.1997.tb01545.x

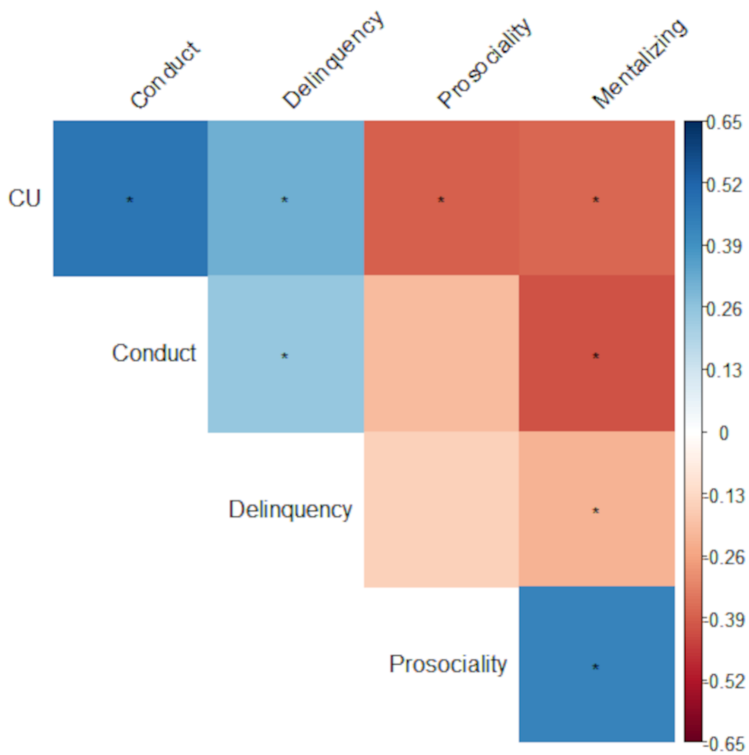
Supplemental figures



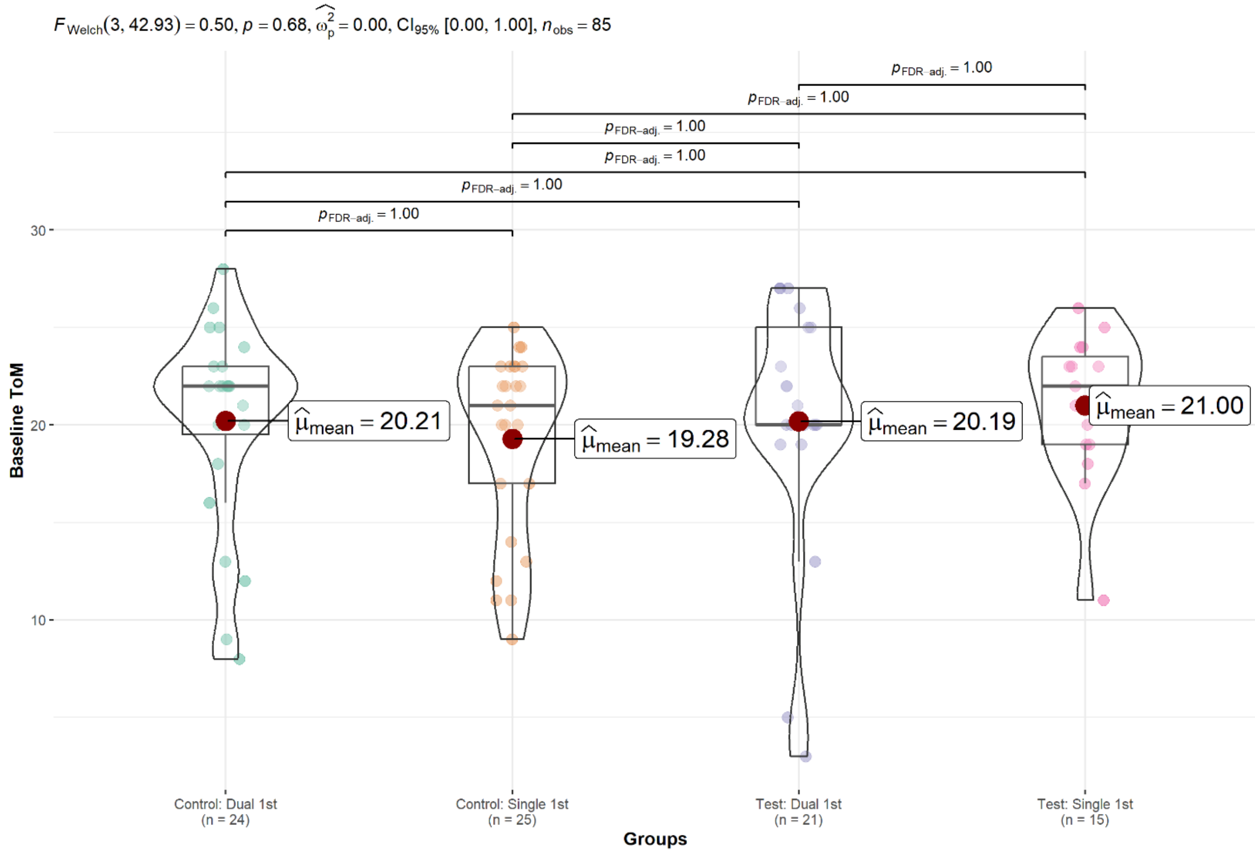
Supplemental Figure 1. Task schematics. A) Selective Stimulus Stop Signal Task, B) Theory of Mind Task, C) Dual-Task



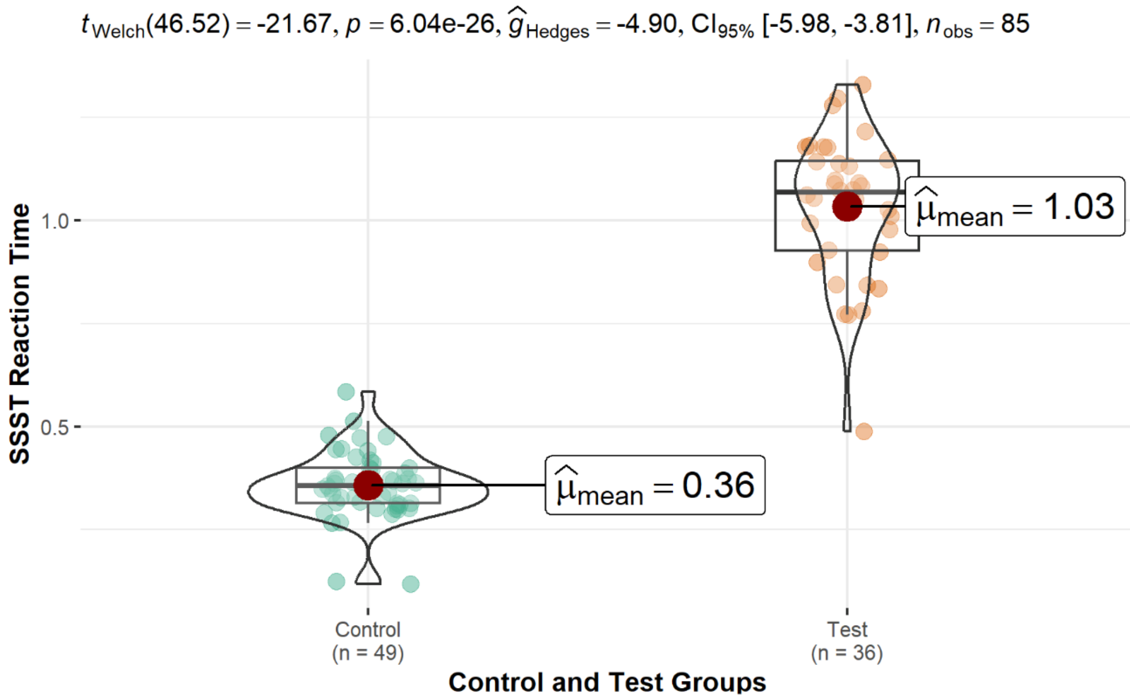
Supplemental Figure 2. Statistical figures on proportion of clinically indicated phenotypes by group. A) Callous-Unemotional traits, B) Conduct Disorder, C) ADHD, D) internalizing



Supplemental Figure 3. Phenotypic associations to show expected relationships commensurate with the literature. Note: *= p<0.05



Supplemental Figure 4. Between group and order test on baseline theory of mind.



Supplemental Figure 5. Between control and test groups on reaction time during stimulus selective stop signal task.

Supplemental tables

Supplementary Table 1: Proportion of Clinical Indicators by Phenotype for CU traits

	CD				ADHD				Internalizing			
	Normative		Elevated		Normative		Elevated		Normative		Elevated	
Clinical % by	%CU	%CD	%CU	%CD	%CU	%ADHD	%CU	%ADHD	%CU	%Int	%CU	%Int
CU Normative	91%	57%	9%	27%	89%	62%	11%	23%	89%	56%	11%	33%
CU Elevated	73%	43%	27%	73%	59%	38%	41%	77%	76%	44%	24%	67%

Note: CU = Callous-Unemotional Traits; CD = Conduct Disorder; ADHD = Attention Deficit Hyperactivity Disorder; Int = Internalizing

Supplemental Table 2. Overall ToM Accuracy Change from Single-Task to Dual-Task

					Bootstrapped CI 95%	
	β	se	t	p	Lower	Upper
Intercept	11.339*	3.300	3.268	0.002	4.820	17.797
CU traits	0.326	2.034	0.154	0.878	-3.760	4.256
CP	-4.542*	2.028	-2.120	0.038	-8.500	-0.565
Sex (Male)	-0.056	1.124	-0.047	0.962	-2.290	2.150
Race (White)	1.588	1.171	1.292	0.201	-0.645	3.908
IQ	0.060	0.031	1.819	0.073	-0.001	0.119
Response Carelessness	-1.982	1.325	-1.416	0.161	-4.620	0.605
ADHD	2.374	1.324	1.708	0.092	-0.249	4.967
Internalizing	1.567	1.858	0.803	0.425	-2.110	5.184
Time	-0.703*	0.353	-2.136	0.036	-1.390	-0.008
Group	-0.181	1.045	-0.162	0.872	-2.230	1.876
Order	1.921	1.097	1.683	0.097	-0.226	4.118
Interactions^{+}						
CU*Time*Group	-8.050*	3.332	-2.575	0.012	-14.600	-1.553
CP *Time*Group	-4.510	6.188	-0.776	0.440	-16.500	7.716
CU* CP *Time*Group	10.119	7.199	1.508	0.135	-4.050	24.068
Random Variance						
Individual Variance	19.537	3.971				
Residual Variance	4.397	0.451				
R^2						
Marginal (fixed effects)	0.192					
Conditional (random effects)	0.807					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

$^{+}$ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant ($p < 0.05$) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 3. Affective ToM Accuracy Change from Single-Task to Dual-Task

	β	se	t	p	Bootstrapped CI 95% Lower	Bootstrapped CI 95% Upper
Intercept	4.786*	1.337	3.392	0.001	2.119	7.371
CU traits	-0.454	0.824	-0.522	0.604	-2.050	1.163
CP	-1.728	0.835	-1.976	0.052	-3.351	-0.110
Sex (Male)	-0.010	0.456	-0.022	0.983	-0.917	0.876
Race (White)	0.177	0.477	0.356	0.723	-0.755	1.118
IQ	0.020	0.013	1.488	0.141	-0.004	0.044
Response Carelessness	-0.739	0.542	-1.304	0.196	-1.812	0.312
ADHD	0.777	0.537	1.378	0.173	-0.282	1.821
Internalizing	0.842	0.758	1.062	0.292	-0.633	2.325
Time	-0.327	0.194	-1.782	0.078	-0.710	0.047
Group	-0.660	0.427	-1.472	0.146	-1.488	0.179
Order	0.826	0.430	1.811	0.074	-0.009	1.671
Interactions+						
CU*Time*Group	-5.475*	1.852	-3.142	0.002	-9.099	-1.836
CP *Time*Group	-3.068	3.423	-0.947	0.346	-9.689	3.686
CU* CP *Time*Group	7.232	3.913	1.964	0.053	-0.493	14.828
Random Variance						
Individual Variance	2.854	0.595				
Residual Variance	1.682	0.177				
R^2						
Marginal (fixed effects)	0.165					
Conditional (random effects)	0.664					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

+ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant ($p < 0.05$) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 4. Cognitive ToM Accuracy Change from Single-Task to Dual-Task

	β	se	t	p	Bootstrapped CI 95% Lower	Upper
Intercept	3.471*	1.288	2.573	0.012	0.977	6.000
CU traits	0.761	0.799	0.915	0.364	-0.784	2.334
CP	-1.189	0.805	-1.419	0.160	-2.787	0.409
Sex (Male)	-0.171	0.440	-0.370	0.713	-1.040	0.701
Race (White)	0.261	0.460	0.548	0.586	-0.636	1.163
IQ	0.020	0.012	1.556	0.124	-0.004	0.043
Response Carelessness	-0.542	0.518	-0.997	0.322	-1.557	0.494
ADHD	0.639	0.518	1.182	0.241	-0.382	1.654
Internalizing	0.080	0.727	0.106	0.916	-1.373	1.502
Time	-0.048	0.179	-0.289	0.774	-0.398	0.302
Group	0.409	0.410	0.951	0.345	-0.394	1.202
Order	0.459	0.424	1.050	0.298	-0.361	1.297
Interactions⁺						
CU*Time*Group	-1.286	1.697	-0.818	0.416	-4.556	2.048
CP *Time*Group	0.034	3.122	0.011	0.992	-6.129	6.088
CU* CP *Time*Group	0.904	3.564	0.273	0.786	-5.990	7.868
Random Variance						
Individual Variance	2.854	0.679				
Residual Variance	1.682	0.207				
R^2						
Marginal (fixed effects)	0.124					
Conditional (random effects)	0.683					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

⁺ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant (p< 0.05) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 5. Physical Accuracy Change from Single-Task to Dual-Task

	β	se	t	p	Bootstrapped CI 95% Lower	Bootstrapped CI 95% Upper
Intercept	3.071*	1.279	2.308	0.024	0.576	5.565
CU traits	0.007	0.785	0.009	0.993	-1.529	1.544
CP	-1.610	0.782	-1.950	0.055	-3.140	-0.113
Sex (Male)	0.125	0.429	0.275	0.784	-0.714	0.962
Race (White)	1.150	0.446	2.443	0.017	0.291	2.030
IQ	0.020	0.012	1.594	0.116	-0.003	0.044
Response Carelessness	-0.701	0.505	-1.308	0.195	-1.683	0.281
ADHD	0.958	0.506	1.800	0.076	-0.045	1.943
Internalizing	0.646	0.707	0.864	0.391	-0.756	2.017
Time	-0.328	0.179	-1.933	0.057	-0.677	0.025
Group	0.070	0.403	0.166	0.869	-0.715	0.854
Order	0.669	0.413	1.554	0.125	-0.135	1.490
Interactions⁺						
CU*Time*Group	-1.287	1.720	-0.801	0.425	-4.649	2.133
CP *Time*Group	-1.474	3.196	-0.492	0.624	-7.686	4.917
CU* CP *Time*Group	1.431	3.651	0.421	0.675	-5.799	8.586
Random Variance						
Individual Variance	2.568	0.748				
Residual Variance	1.594	1.116				
R^2						
Marginal (fixed effects)	0.206					
Conditional (random effects)	0.690					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

$^+$ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant ($p < 0.05$) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 6. Overall ToM Reaction Time Change from Single-Task to Dual-Task

					Bootstrapped CI 95%	
	β	se	t	p	Lower	Upper
Intercept	2.433*	0.591	3.950	0.000	1.261	3.583
CU traits	0.024	0.364	0.063	0.950	-0.688	0.741
CP	0.193	0.361	0.510	0.612	-0.532	0.892
Sex (Male)	-0.131	0.202	-0.624	0.534	-0.525	0.264
Race (White)	-0.022	0.206	-0.100	0.921	-0.422	0.379
IQ	0.002	0.006	0.309	0.758	-0.009	0.013
Response Carelessness	-0.297	0.234	-1.200	0.234	-0.761	0.154
ADHD	-0.007	0.235	-0.031	0.976	-0.474	0.461
Internalizing	-0.001	0.330	-0.002	0.998	-0.651	0.636
Time	0.071	0.097	0.781	0.437	-0.119	0.262
Group	0.027	0.187	0.138	0.890	-0.339	0.395
Order	0.081	0.191	0.401	0.689	-0.293	0.458
Interactions+						
CU*Time*Group	2.067*	0.922	2.404	0.019	0.276	3.914
CP *Time*Group	2.226	1.725	1.392	0.168	-1.166	5.528
CU* CP *Time*Group	-3.089	1.995	-1.675	0.098	-6.892	0.878
Random Variance						
Individual Variance	0.508	0.131				
Residual Variance	0.707	0.092				
R^2						
Marginal (fixed effects)	0.061					
Conditional (random effects)	0.539					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

+ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant ($p < 0.05$) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 7. Affective ToM Reaction Time Change from Single-Task to Dual-Task

					Bootstrapped CI 95%	
	β	se	t	p	Lower	Upper
Intercept	2.326*	0.668	3.362	0.001	0.988	3.640
CU traits	0.111	0.410	0.260	0.795	-0.700	0.933
CP	0.085	0.410	0.199	0.843	-0.726	0.884
Sex (Male)	-0.107	0.227	-0.456	0.650	-0.546	0.342
Race (White)	0.072	0.232	0.296	0.768	-0.386	0.529
IQ	0.003	0.006	0.476	0.635	-0.009	0.016
Response Carelessness	-0.314	0.264	-1.131	0.262	-0.825	0.208
ADHD	0.037	0.265	0.135	0.893	-0.485	0.564
Internalizing	0.014	0.370	0.038	0.970	-0.697	0.736
Time	0.065	0.102	0.679	0.499	-0.135	0.265
Group	-0.007	0.211	-0.033	0.974	-0.416	0.413
Order	0.084	0.214	0.378	0.707	-0.330	0.513
Interactions⁺						
CU*Time*Group	2.483*	0.970	2.736	0.008	0.583	4.417
CP *Time*Group	2.192	1.820	1.300	0.197	-1.433	5.758
CU* CP *Time*Group	-3.414	2.061	-1.781	0.079	-7.438	0.725
Random Variance						
Individual Variance	0.665	0.168				
Residual Variance	0.809	0.103				
R^2						
Marginal (fixed effects)	0.062					
Conditional (random effects)	0.582					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

⁺ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant ($p < 0.05$) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 8. Cognitive ToM Reaction Time Change from Single-Task to Dual-Task

					Bootstrapped CI 95%	
	β	se	t	p	Lower	Upper
Intercept	2.334*	0.630	3.562	0.001	1.099	3.568
CU traits	0.022	0.389	0.055	0.956	-0.750	0.800
CP	0.215	0.386	0.528	0.599	-0.555	0.962
Sex (Male)	-0.083	0.216	-0.371	0.712	-0.504	0.337
Race (White)	-0.065	0.219	-0.282	0.779	-0.500	0.364
IQ	0.003	0.006	0.442	0.660	-0.009	0.014
Response Carelessness	-0.388	0.249	-1.477	0.144	-0.882	0.098
ADHD	0.083	0.250	0.319	0.751	-0.407	0.580
Internalizing	-0.096	0.354	-0.259	0.796	-0.790	0.598
Time	0.130	0.110	1.267	0.209	-0.085	0.345
Group	0.018	0.200	0.086	0.932	-0.369	0.403
Order	0.136	0.202	0.643	0.522	-0.262	0.534
Interactions+						
CU*Time*Group	2.318*	1.058	2.369	0.020	0.245	4.442
CP *Time*Group	2.600	1.966	1.429	0.157	-1.312	6.453
CU* CP *Time*Group	-3.569	2.241	-1.726	0.088	-7.895	0.848
Random Variance						
Individual Variance	0.544	0.154				
Residual Variance	0.730	0.105				
R^2						
Marginal (fixed effects)	0.082					
Conditional (random effects)	0.504					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

+ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant ($p < 0.05$) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 9. Physical ToM Reaction Time Change from Single-Task to Dual-Task

	β	se	t	p	Bootstrapped CI 95% Lower	Bootstrapped CI 95% Upper
Intercept	2.663*	0.527	4.842	0.000	1.645	3.700
CU traits	-0.039	0.323	-0.115	0.909	-0.670	0.590
CP	0.250	0.323	0.733	0.466	-0.399	0.878
Sex (Male)	-0.203	0.180	-1.088	0.281	-0.557	0.142
Race (White)	-0.073	0.185	-0.375	0.709	-0.433	0.288
IQ	0.000	0.005	-0.086	0.932	-0.010	0.009
Response Carelessness	-0.189	0.209	-0.858	0.394	-0.600	0.212
ADHD	-0.143	0.209	-0.654	0.515	-0.552	0.270
Internalizing	0.077	0.295	0.253	0.801	-0.507	0.646
Time	0.016	0.104	0.170	0.866	-0.187	0.219
Group	0.071	0.167	0.406	0.686	-0.254	0.394
Order	-0.041	0.168	-0.233	0.816	-0.369	0.294
Interactions+						
CU*Time*Group	1.402	0.979	1.518	0.133	-0.496	3.311
CP *Time*Group	1.890	1.840	1.099	0.275	-1.741	5.463
CU* CP *Time*Group	-3.090	2.097	-1.581	0.118	-7.167	1.033
Random Variance						
Individual Variance	0.337	0.099				
Residual Variance	0.574	0.087				
R^2						
Marginal (fixed effects)	0.066					
Conditional (random effects)	0.404					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

+ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant ($p < 0.05$) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 10. Affective > Physical ToM Accuracy Change from Single-Task to Dual-Task

					Bootstrapped CI 95%	
	β	se	t	p	Lower	Upper
Intercept	-0.245	1.131	-0.202	0.840	-2.490	1.979
CU traits	-0.458	0.704	-0.621	0.537	-1.824	0.935
CP	-0.899	0.714	-1.211	0.230	-2.296	0.482
Sex (Male)	-0.075	0.386	-0.184	0.855	-0.841	0.684
Race (White)	-0.416	0.403	-0.981	0.330	-1.209	0.370
IQ	0.009	0.011	0.841	0.403	-0.011	0.031
Response Carelessness	-0.378	0.459	-0.787	0.434	-1.289	0.522
ADHD	0.283	0.457	0.593	0.555	-0.632	1.179
Internalizing	0.509	0.642	0.757	0.452	-0.755	1.772
Time	-0.158	0.201	-0.830	0.409	-0.562	0.231
Group	-0.696	0.364	-1.831	0.071	-1.411	0.020
Order	0.481	0.363	1.243	0.218	-0.232	1.203
Interactions+						
CU*Time*Group	-4.812*	1.935	-2.663	0.009	-8.573	-0.972
CP *Time*Group	-2.309	3.544	-0.688	0.494	-9.197	4.643
CU* CP *Time*Group	6.495	4.057	1.701	0.093	-1.448	14.367
Random Variance						
Individual Variance	1.793	0.450				
Residual Variance	1.328	0.170				
R^2						
Marginal (fixed effects)	0.119					
Conditional (random effects)	0.518					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

+ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant ($p < 0.05$) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 11. Cognitive > Physical ToM Accuracy Change from Single-Task to Dual-Task

					Bootstrapped CI 95%	
	β	se	t	p	Lower	Upper
Intercept	-1.013	0.916	-1.048	0.298	-2.786	0.808
CU traits	0.758	0.566	1.278	0.206	-0.330	1.867
CP	-0.264	0.568	-0.442	0.660	-1.387	0.838
Sex (Male)	-0.242	0.311	-0.738	0.463	-0.857	0.366
Race (White)	-0.400	0.326	-1.175	0.244	-1.035	0.237
IQ	0.008	0.009	0.913	0.364	-0.009	0.025
Response Carelessness	-0.140	0.367	-0.361	0.719	-0.858	0.582
ADHD	0.088	0.367	0.227	0.821	-0.636	0.814
Internalizing	-0.290	0.517	-0.536	0.594	-1.333	0.698
Time	0.140	0.204	0.739	0.462	-0.258	0.537
Group	0.368	0.294	1.202	0.234	-0.207	0.944
Order	0.075	0.297	0.239	0.812	-0.508	0.659
Interactions+						
CU*Time*Group	-0.543	1.949	-0.302	0.763	-4.339	3.327
CP *Time*Group	0.887	3.595	0.264	0.792	-6.230	7.946
CU* CP *Time*Group	-1.026	4.150	-0.264	0.792	-9.210	7.048
Random Variance						
Individual Variance	0.887	0.319				
Residual Variance	0.925	0.178				
R^2						
Marginal (fixed effects)	0.095					
Conditional (random effects)	0.331					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

+ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant (p< 0.05) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 12. Affective > Cognitive ToM Accuracy Change from Single-Task to Dual-Task

					Bootstrapped CI 95%	
	β	se	t	p	Lower	Upper
Intercept	-0.574	1.175	-0.460	0.647	-2.921	1.729
CU traits	-0.820	0.725	-1.075	0.286	-2.235	0.625
CP	-1.158	0.737	-1.509	0.136	-2.615	0.297
Sex (Male)	0.072	0.400	0.169	0.867	-0.720	0.862
Race (White)	0.052	0.420	0.119	0.906	-0.774	0.880
IQ	0.010	0.011	0.881	0.381	-0.011	0.032
Response Carelessness	-0.479	0.474	-0.965	0.338	-1.409	0.444
ADHD	0.470	0.469	0.952	0.345	-0.458	1.393
Internalizing	0.803	0.661	1.155	0.252	-0.490	2.113
Time	-0.304	0.201	-1.602	0.113	-0.706	0.089
Group	-0.856*	0.375	-2.177	0.033	-1.580	-0.115
Order	0.606	0.373	1.514	0.135	-0.120	1.341
Interactions⁺						
CU*Time*Group	-4.858*	1.922	-2.694	0.009	-8.593	-1.126
CP *Time*Group	-3.085	3.565	-0.920	0.360	-10.050	3.873
CU* CP *Time*Group	6.798	4.072	1.784	0.078	-1.202	14.802
Random Variance						
Individual Variance	1.972	0.461				
Residual Variance	1.395	0.166				
R^2						
Marginal (fixed effects)	0.136					
Conditional (random effects)	0.550					

Note: We can only interpret the interaction terms as they account for group comparisons across time. Also, parameters are bootstrapped corrected using 10,000 resamples

$^+$ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant (p< 0.05) for two-tailed test with bootstrapped corrected p-values

Table 13. Dual-Task Effects

	β	se	t	p	Bootstrapped CI 95% Lower	Bootstrapped CI 95% Upper
Intercept	0.057	0.259	0.221	0.830	-0.399	0.511
CU traits	0.000	0.139	0.003	0.998	-0.247	0.260
CP	0.058*	0.028	2.090	0.040	0.007	0.109
Sex (Male)	0.135	0.077	1.756	0.083	-0.004	0.276
Race (White)	-0.094	0.080	-1.178	0.243	-0.239	0.051
IQ	-0.001	0.002	-0.451	0.653	-0.005	0.003
Response Carelessness	-0.162	0.090	-1.795	0.077	-0.326	0.004
ADHD	-0.010	0.018	-0.555	0.581	-0.043	0.022
Internalizing	-0.004	0.013	-0.294	0.769	-0.027	0.019
Group	-0.138*	0.072	-1.924	0.048	-0.268	-0.007
Order	-0.129	0.104	-1.235	0.221	-0.317	0.063
Interactions+						
CU *Group	-0.885*	0.377	-2.345	0.022	-1.584	-0.207
CP *Group	-0.273	0.155	-1.767	0.082	-0.558	0.007
CU* CP *Group	0.335	0.171	1.957	0.058	-0.027	0.652
Random Variance						
Individual Variance	-0.004	0.005				
Residual Variance	0.317	0.280				
R^2						
Model R^2	0.178					

Note: We can only interpret the interaction terms as they account for group comparisons (we do not interact with time in this model because dual task effects are a singular metric using both timepoints to derive a single metric). Also, (1) parameters are bootstrapped corrected using 10,000 resamples; (2) negative values indicate greater difficulty for the dual-task (greater dual-task effect).

+ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant (p< 0.05) for two-tailed test with bootstrapped corrected p-values

Table 14. Delinquency as a Function of Resilience to Cognitive Demands

					Bootstrapped CI 95%	
	β	se	t	p	Lower	Upper
Intercept	0.207	0.341	0.608	0.999	-0.384	0.799
Change after load	-0.032	0.192	-0.167	0.868	-0.368	0.304
CU traits	-0.011	0.013	-0.794	0.430	-0.034	0.013
CP	0.052	0.061	0.844	0.402	-0.055	0.159
Sex (Male)	-0.189	0.113	-1.673	0.099	-0.387	0.008
Race (White)	0.001	0.003	0.174	0.862	-0.005	0.006
IQ	0.214	0.143	1.501	0.138	-0.035	0.464
Response Carelessness	-0.134	0.117	-1.141	0.258	-0.338	0.071
ADHD	0.072	0.027	2.734	0.008	0.026	0.119
Internalizing	-0.010	0.019	-0.527	0.600	-0.043	0.023
Group	-0.146	0.188	-0.778	0.439	-0.475	0.182
Order	0.201	0.126	1.600	0.999	0.002	0.400
Interactions+						
CU *Group*change	-1.168	0.549	-2.129	0.037	-2.126	-0.210
CP *Group*change	0.286	0.151	1.899	0.062	0.023	0.550
CU* CP *Group*change	-0.400	0.280	-1.428	0.158	-0.890	0.089
Random Variance						
Individual Variance	0.071	0.388				
Residual Variance	0.052	0.048				
R^2						
Model R^2	0.338					

Note: We can only interpret the interaction terms as they account for group comparisons (we do not interact with time in this model because delinquency is a singular metric being predicted by change after a cognitive load using both timepoints to derive a single metric). Also, (1) parameters are bootstrapped corrected using 10,000 resamples; (2) negative values indicate greater difficulty for the dual-task (greater dual-task effect).

+ = all levels of interaction were tested in the full model, but the interpreted interactions listed

* = statistically significant ($p< 0.05$) for two-tailed test with bootstrapped corrected p-values

Supplemental Table 15. Baseline ToM Overall Accuracy

	β	se	t	p
Intercept	11.670	3.486	3.348	0.001
CU traits	1.846	2.113	0.874	0.385
CP	-1.044*	0.444	-2.353	0.021
Sex (Male)	-0.844	1.186	-0.711	0.479
Race (White)	1.528	1.201	1.273	0.207
IQ	0.064	0.033	1.944	0.056
Response Carelessness	-2.438	1.416	-1.721	0.089
ADHD	0.436	0.276	1.578	0.119
Internalizing	0.127	0.195	0.653	0.516

Note: Linear regression results with *= p< 0.05

Supplemental Table 16. Baseline ToM Affective Accuracy

	β	se	t	p
Intercept	5.128	1.510	3.395	0.001
CU traits	0.416	0.916	0.454	0.651
CP	-0.449*	0.192	-2.333	0.022
Sex (Male)	-0.718	0.514	-1.397	0.167
Race (White)	0.246	0.520	0.473	0.638
IQ	0.019	0.014	1.321	0.190
Response Carelessness	-0.864	0.614	-1.408	0.163
ADHD	0.159	0.120	1.324	0.190
Internalizing	0.030	0.084	0.356	0.723

Note: Linear regression results with *= p< 0.05

Supplemental Table 17. Baseline ToM Cognitive Accuracy

	β	se	t	p
Intercept	3.191	1.389	2.297	0.024
CU traits	0.940	0.842	1.116	0.268
CP	-0.330	0.177	-1.865	0.066
Sex (Male)	-0.231	0.473	-0.489	0.626
Race (White)	0.224	0.478	0.469	0.641
IQ	0.027*	0.013	2.054	0.043
Response Carelessness	-0.681	0.564	-1.206	0.231
ADHD	0.111	0.110	1.009	0.316
Internalizing	0.035	0.078	0.451	0.653

Note: Linear regression results with *= p< 0.05

Supplemental Table 18. Baseline ToM Physical Accuracy

	β	se	t	p
Intercept	3.352	1.264	2.652	0.010
CU traits	0.491	0.766	0.640	0.524
CP	-0.266	0.161	-1.651	0.103
Sex (Male)	0.105	0.430	0.245	0.807
Race (White)	1.058*	0.435	2.432	0.017
IQ	0.018	0.012	1.526	0.131
Response Carelessness	-0.893	0.513	-1.739	0.086
ADHD	0.167	0.100	1.663	0.101
Internalizing	0.062	0.071	0.879	0.382

Note: Linear regression results with *= p< 0.05