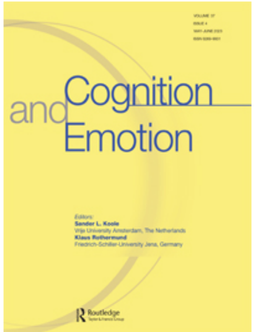

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Affective theory of mind impairments underlying callous-unemotional traits and the role of cognitive control

Drew E. Winters and Joseph T. Sakai

Department of Psychiatry, University of Colorado School of Medicine, Anschutz Medical Campus, Aurora, CO, USA

ABSTRACT

Affective theory of mind (aToM) impairments associated with the youth antisocial phenotype callous-unemotional (CU) traits predict antisocial behaviour above CU traits alone. Importantly, CU traits associate with decrements in complex but not basic aToM. aToM is modulated by cognitive control and CU traits associate with cognitive control impairments; thus, cognitive control is a plausible mechanism underlying aToM impairments in CU traits. Because cognitive control is dependent on the availability of cognitive resources, youth with CU traits may have difficulty with allocating cognitive resources under greater demands that impact complex aToM. To test this, 81 participants (ages 12–14, Female = 51.8%, Male = 48.2%) were recruited to complete a behavioural paradigm that involved an initial aToM task with complex and basic emotions followed by placing additional demands on cognitive control and a final repeat of the same aToM task. Results indicate adolescents higher in CU traits had intact basic aToM but less accuracy in complex aToM that worsened after taxing cognitive control; and this load only required a short duration to account for ToM decrements (200 ms [range 150–1600 ms]). These results demonstrate CU traits association with cognitive control limitations that impact complex aToM. This may partially explain antisocial behaviour associated with CU traits.

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Antisocial behaviour (e.g. violent criminal behaviour) amongst adolescents with callous-unemotional (CU) traits is predicted by impairments in affective theory of mind (aToM) above clinical ratings of CU traits alone (Gillespie et al., 2018; Song et al., 2016). CU traits are a youth antisocial phenotype (Frick & White, 2008) important in the diagnosis of conduct disorder for youth low empathy, remorse, and guilt called the "low prosocial emotion specifier" (American Psychiatric Association, 2013: DSM-5). CU traits represent the affective dimension of adult psychopathy (Barry et al., 2000; Frick et al., 2014). Psychopathy has developmental underpinnings in youth (Frick & Viding, 2009) with primary aetiological theories centring on either affective or cognitive impairments (e.g. cognitive control, attention). Affective impairment findings have been highly replicable; however, multiple studies converge that these affective impairments only occur when stimuli are presented outside the individuals focus of attention (for reviews: Baskin-Sommers & Newman, 2013; Hamilton et al., 2015). Further work has demonstrated this effect in a theory of mind task (Drayton et al., 2018) and inhibitory processing tasks (Gluckman et al., 2016) indicating a limited capacity to monitor contextual information and use that information to regulate goal directed behaviours – or cognitive control (Botvinick et al., 2001). Cognitive control modulates theory of mind via inhibiting responses and flexibly shifting awareness (for reviews: Mahy et al., 2014; Wade et al., 2018) to infer another's thoughts (cognitive theory of mind) or emotions

CONTACT Drew E. Winters drewewinters@gmail.com Department of Psychiatry, University of Colorado School of Medicine, Anschutz Medical Campus, Aurora, 80045-2559, CO, USA
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(aToM) (Shamay-Tsoory et al., 2010). Impairments in aToM associated with CU traits are specific to complex emotions (for review: Tillem et al., 2020), which require greater cognitive resources to process and detect (Yates et al., 2010). Thus, aToM impairments may be explained by a limitation in cognitive resources. The present study therefore examines whether placing additional demands on resources for cognitive control has an impact on aToM in adolescents with CU traits.

Aetiological theories of psychopathic traits emphasise affect, cognitive attention processes, and their interplay. For example, both psychopathic traits in adults and CU traits in youth associate with impairments recognising others' emotions, particularly fear and distress cues (Blair, 2008; Hawes & Dadds, 2012), which is thought to be a fundamental risk pathway for developing psychopathy (Blair, 2008; Blair & Mitchell, 2009). Other evidence suggests that impairments in emotion processing and affect can largely be explained by an exaggerated attention "bottleneck" at the early stages of attention that prohibits allocating attention to and processing peripheral stimuli after goal directed attention is set (i.e. response modulation hypothesis; Hamilton & Newman, 2018; Lorenz & Newman, 2002; Newman et al., 2010). Support for this view suggests that replicable findings from the affective perspective do not hold when stimuli are placed on the periphery of their attention (for reviews: Baskin-Sommers & Newman, 2013; Hamilton et al., 2015). This effect is commonly demonstrated in inhibitory processing paradigms that measure cognitive control. For example, adults with psychopathy demonstrate greater focus during the Stroop task when conflicting stimuli are present in a consistent location but when placed on the periphery of their attentional focus there are substantial difficulties (Hiatt et al., 2004), which was also demonstrated in adolescents with CU traits, suggesting impairments in cognitive control (Gluckman et al., 2016). This flexible adaptation towards goal relevant stimuli can be reduced under higher levels of cognitive load on cognitive control resources (for reviews: Lavie, 2005; Murphy et al., 2016). Thus, the load on cognitive resources may in part account for limitations in cognitive control.

Although not sufficient, cognitive control is necessary for theory of mind (for reviews: Mahy et al., 2014; Wade et al., 2018), which may explain impairments observed in youth with CU traits. Theory of mind is divided in to cognitive and affective components; where *cognitive theory of mind* involves the inference of other people's thoughts and beliefs, *affective theory of mind* (aToM) involves making inferences about others' emotions (Shamay-Tsoory et al., 2010). This is an important distinction because adolescents with CU traits show the ability for cognitive theory of mind (Roberts et al., 2020), but, when compared to typically developing peers, they demonstrate impairments in aToM during complex emotions (Sharp et al., 2015; Sharp & Vanwoerden, 2014; Tillem et al., 2020). Complex emotions (e.g. nervousness, boredom, and shame) are more nuanced than basic emotions (e.g. happy, sad, and scared) (Baron-Cohen et al., 1997; Ekman, 1992) and require more cognitive resources to process (Yates et al., 2010) because their subtlety requires monitoring contextually relevant social information (Barrett et al., 2011). This processing of complex emotional information during aToM is modulated by cognitive control via inhibition and shifting awareness to cue into another's emotional state (for review: Wade et al., 2018). Together, this evidence suggests that load and resources for cognitive control may be critical for aToM as well. Given that aToM associates with prosocial behaviour (for meta-analysis: Imuta et al., 2016); but aToM impairments predict antisocial behaviour above clinical ratings of CU traits (Gillespie et al., 2018; Song et al., 2016), it is critical that we investigate aToM impairments in youth with CU traits in relation to the load on resources for cognitive control.

aToM uniquely predicts antisocial behaviour above CU traits alone, here we review evidence this may be due to cognitive control deficits. For example, Gillespie et al. (2018) revealed that poor aToM accuracy predicted proactive aggression (but not reactive aggression) above CU traits. This suggests either (1) poor aToM contributes to premeditated rather than reactive violent acts in those with CU traits or (2) that those higher in CU traits are more likely to allocate cognitive control resources towards proactive regression rather than processing affect. Song et al. (2016) conducted a longitudinal study that revealed that early childhood CU traits predicted middle to late childhood conduct problems but that this association was accounted for by ToM. Sharp et al. (2015) were the first to reveal decrements in aToM for complex (but not basic) emotions in early adolescents. This is a critical distinction with important clinical implications that has not been replicated in early adolescents. Moreover, those with CU traits may use alternative cognitive strategies to process emotional information suggested by differences in brain activation such as using cognitive assessment rather than affective processing (e.g. Decety et al., 2013) or looking for similarities rather than monitoring context to process conflict in others emotions form their own (e.g. Winters et al., 2023). These alternative strategies may be more cognitively demanding requiring more cognitive resources that they are less likely to expend to process another's affect (for review: Hamilton et al., 2015). Thus, processing affective information may be secondary and the cost of may outweigh the expected benefits by those with CU traits (Blair, 2008; Hamilton et al., 2015; Kurzban et al., 2013), which may be exacerbated and investigated by placing additional demands on cognitive control.

The literature suggests that cognitive control is critical for aToM and that CU traits associate with impairments in both; however less is understood about how resources for cognitive control impacts aToM in these youth. Cognitive resource allocation, according to the expected value of control (EVC) model, undergoes an evaluation of availability of resources and the costs of allocating resources for cognitive control (Shenhav et al., 2013). Placing additional demands on cognitive control makes the available resources more costly to use and reduces the likelihood of being allocated unless there is a significant payoff. Such an evaluation may explain why adults with psychopathy (Baskin-Sommers et al., 2013; Sadeh et al., 2013) and adolescents with CU traits (Sharp et al., 2015) demonstrate difficulty responding to complex affective information but are able to respond when the load is reduced by using less complexity. This is in line with the view that cognitive control processes of inhibition and directing attention modulate aToM (for review: Wade et al., 2018), but suggests there may be a baseline limitation in cognitive resources in those higher in CU traits, which would impact the allocation of cognitive resources to cognitive control for aToM. Additionally, given that complex emotions require greater cognitive resources to process than basic emotions (Yates et al., 2010), adding additional demands on cognitive control would plausibly exacerbate pre-existing limitations on cognitive resources and result in further decrements in complex aToM. However, we do not know how cognitive control modulates aToM in youth with CU traits nor how placing additional demands on cognitive control may exacerbate aToM impairments in these youth. Despite some promising findings treating these symptoms in youth, there are no established treatments (De Brito et al., 2021) and available treatments for antisocial phenotypes demonstrate limited efficacy (for meta-analyses: Lux, 2016; van der Stouwe et al., 2014; for review: White et al., 2022); thus such work is an important step for defining modifiable mechanisms that could be used to develop novel intervention approaches.

The present study takes the next step to advance this line of research by implementing a behavioural paradigm to examine the impact of cognitive control on aToM by introducing additional cognitive demands. Specifically, we limit the attentional field to one location (no peripheral stimuli) and preset goal directed attention via instruction to engage in aToM to isolate cognitive control resources for aToM. We use a widely used inhibitory processing task (i.e. the stop-signal task) frequently used to measure cognitive control (e.g. Verbruggen & Logan, 2008; Zhang & Li, 2012) and tax cognitive control (e.g. Steinbeis, 2018) to place additional demands on cognitive resources using a pre-post design. Cognitive load theory posits that cognitive resources are limited and that placing additional demands on cognitive resources places limitations on how those cognitive resources can be allocated (for reviews: Lavie, 2005; Murphy et al., 2016). The length of time of this effect is largely unknown and may be task dependent (for reviews: Lavie, 2005; Murphy et al., 2016); however, a recent article using the same task as the proposed study Steinbeis (2018) demonstrated and effect which indicates an adequate duration for the design. Thus, we will use the same design to test the impact of a cognitive load on aToM.

Using this design we hypothesise that, prior to a cognitive load, we would replicate findings by Sharp et al. (2015) that CU traits negatively associated with complex aToM but did not significantly associate with basic aToM. Next, given the literature on impairments in cognitive resources, we hypothesised that higher CU traits would associate with a lower level a cognitive control measured by duration of inhibition. Finally, given the importance of cognitive control for aToM (for reviews see: Carlson, 2005; Mahy et al., 2014; Wade et al., 2018), we hypothesised that placing an additional demand on cognitive control would negatively impact complex aToM accuracy (but not basic aToM) at higher levels of CU traits.

Methods

A priori power analysis

Using G*Power (Faul et al., 2007, 2009), we conducted an a priori power analyses for associations between aToM and CU traits and the impact of the inhibitory processing task. From Sharp et al. (2015) we used the reported Pearson correlation between the aToM task and CU trait subscale of the youth psychopathic traits inventory ($r = -0.19$). From Steinbeis (2018) we used the reported Cohen's d that tested the effect of a cognitive load (Cohen's $d = 0.56$). Using the r package "effectsize" (Ben-Shachar et al., 2020), the r value was converted to Cohen's d before converting to f using the conversion published in Cohen (1988) and Cohen's d was converted to r^2 for respective power calculations. Using a two tailed f test for associations between CU traits and aToM suggested a sample of 81 is required to achieve 80% power. Using an exact test for a two-tailed random effects model examining the effects of a cognitive load suggested a sample of 57 participants was required for 80% power.

Recruitment

The study protocol, participant recruitment, and consents were approved by the Colorado Multiple Institutional Review Board. Participants were recruited from the community using online adds, where the study was described as: "The study is designed to test responses to a task involving responses to others' emotions and factors related to how people respond to other emotions. You will be asked to respond to a number of shapes and images of people's faces". As an additional safeguard for online recruitment, acceptance into the study required a responsible adult to upload identification to ensure we did not have repeat participants as well as a verification of participants identity and age. Participants were selected based on age (12–14 years) and predefined recruitment targets involving equal numbers across sex (50/50) and level of CU traits (50/50; high and normative CU traits). To identify those in the high CU trait group, the 9-item split coding method for the low prosocial emotion specifier was used with the Inventory of Callous and Unemotional Traits measure (see section Self-Report Measures for more details; Kimonis et al., 2015; Sakai et al., 2016). Those not meeting the low prosocial emotion specifier were considered normative. Participants meeting the above criteria were excluded if they 1) did not complete consent/assent after research staff provided a courtesy follow up or 2) did not complete the study task within one month after being accepted into the study. The study recruitment goal was to reach 100 participants, but study resources ended at 81 participants.

Sample

The recruited sample consisted of 81 adolescents (ages 12–14: 12.86 ± 0.76) that were relatively balanced between sex (female 51.8%, male 48.2%) and predominately White (White = 69.1%, Black = 17.3%, Pacific Islander = 10%, American Indian = 1.2%, Asian = 1.2%, other race = 1.2%) with 16% reporting Latinx ethnicity. A slightly higher number or participants qualified for LPE versus normative CU traits (LPE = 56.9%, normative = 43.1%; Table 1), which is not unexpected given our recruitment strategy sought to match on LPE specifier (see Recruitment above). Of the 7% meeting self-report cut-offs for conduct problems ($n = 6$) all qualified for the LPE specifier (see supplemental information for additional cut-off information). Although not used as an inclusion/exclusion criterion, all responsible adults were asked if the participant had ever received an autism-spectrum diagnosis, which none were reported.

Study procedure

Participants completed a behavioural paradigm where all participants were exposed to the same conditions. The behavioural paradigm consisted of an initial affective ToM task followed by an inhibitory processing task before completing the same affective ToM task again (see section Behavioural Task Measures for more details). This paradigm took ~33 minutes to complete (~10 minutes for the theory of mind task x2 and ~13 minutes for the inhibitory processing task). Participants completed these tasks online with a computer (no mobile devices allowed) using the behavioural task platform Testable (Rezlescu et al., 2020). Participants received one link that was good for one access to the study and required the 5-digit code and email address they signed up with to access. This information was given prior to ensure participants had adequate internet access and set aside time – without distractions –

Table 1. Descriptives and correlations.

Variable	Mean ± SD (range or *n*(%))	Correlations										
		2	3	4	5	6	7	8	9	10	11[a]	12[b]
1.CU traits	30.23 ± 6.68 (18–44)	0.56*	−0.20*	−0.26*	−0.09	−0.30*	−0.23*	−0.12	−0.26*	0.03	0.07	0.00
2.Conduct problems	1.51 ± 1.71 (0–8)		−0.12	−0.13	−0.17	−0.04	−0.19*	−0.11	−0.20	−0.03	0.11	0.17
3.Max cognitive load	1068 ± 525(150–1600)			0.13	−0.04	0.22	0.20*	0.06	0.24*	0.25*	−0.04	−0.04
4.ToM baseline total	19.24 ± 3.28(10–27)				0.75*	0.84*	0.64*	0.49*	0.61*	0.04	−0.16	−0.03
5.ToM baseline basic	6.72 ± 1.85(1–10)					0.26*	0.46*	0.45*	0.38*	0.04	−0.07	0.05
6.ToM baseline complex	12.93 ± 2.27(5–17)						0.55*	0.34*	0.58*	0.02	−0.1	−0.18
7.ToM post load total	18.83 ± 4.59(5–26)							0.82*	0.94*	0.08	−0.08	−0.07
8.ToM post load basic	6.46 ± 1.97(2–10)								0.56*	0.06	−0.12	0.00
9.ToM post load complex	12.37 ± 3.18(3–17)									0.08	−0.09	−0.03
10.Age	12.89 ± 0.76 (12–14)											
11.Sex[a]											0.03	−0.09
Female	42(51.8%)											0.06
Male	39(48.2%)											
12.Race [b]												–
White	56(69.1%)											
Black	14(17.3%)											
Pacific Islander	8(10%)											
American Indian	1(1.2%)											
Asian	1(1.2%)											
Other Race	1(1.2%)											

[a]Coded 1 for male, 0 for female, Spearman correlation.
[b]Coded 1 for White and 0 for non-white, Spearman correlation.
*$p < 0.05$.

for the duration of the study. Participants that completed the study were reimbursed $10 (participants could not advance through the study without responding) and no data was recorded for participants that did not complete the study in full. Importantly, the foci of attention for the tasks were in one location and participants were explicitly instructed to engage in aToM to orient goal directed attention. This design allows us to examine the impact of taxing cognitive control on aToM.

Self-report measures

Callous-unemotional traits

CU traits was assessed using the 24-item self-report measure Inventory of Callous-Unemotional Traits (ICU; Frick, 2004). Previous research demonstrates two items on the ICU have poor psychometric properties and were removed from our analyses, consistent with previous studies (Kimonis et al., 2015). We found adequate reliability for this measure in our current sample (ω = 0.86). The ICU consists of three subscales for callousness (ω = 0.81; e.g. "I do not care who I hurt to get what I want"), uncaring (ω = 0.696; e.g. reverse scored: "I care about how well I do at school or work"), and unemotional (ω = 0.72; e.g. "I do not show my emotions to others"). Although previous research indicates that the unemotional subscale does not associate with antisocial behaviour or the other subscales (Cardinale & Marsh, 2020), the unemotional subscale is critical for capturing the affective and interpersonal features of this construct that is independent of antisocial behaviour; thus, removing these items would diminish the overall measure for the construct of interest (Colins et al., 2016). We included the unemotional subscale in our analysis. Participants rate items on a four-point Likert scale from 0 ("not true at all") to 3 ("definitely true"). Higher scores indicate greater level of CU traits.

We calculated the low prosocial emotion specifier using 9-items from this measure and the split coding method (Kimonis et al., 2015). This criterion was chosen because of the methods to identify those with low prosocial emotions, the 9-item split coding method had the best reliability (0.72 versus the other methods 0.42–0.7; Kimonis et al., 2015). Using this method coding method, Kimonis et al. (2015) suggests that 40.3% of boys and 27.6% of girls will meet criteria for low prosocial emotions.

Conduct problems

Conduct problems were assessed using the conduct problem subscale of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997; Goodman et al., 2003). The SDQ is a brief behavioural screening with versions to assess youth between 3 and 16 years old that demonstrates test-retest reliability, internal consistency, and cross-informant correlation (Goodman, 2001; Goodman et al., 2003). The conduct problem subscale consists of five items that had adequate reliability in our current sample (ω = 0.79). 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 conduct problems.

Affective valence

Affect valence can impact cognitive performance (Sadeh et al., 2013) and tasks used to elicit a cognitive load (i.e. stop signal task) can primarily evoke negative affect such as frustration and annoyance (Spunt et al., 2012). Thus, Affective valence was assessed using a self-report measure where participants rated the question "how annoyed are you?" on a visual analogue scale from 0-100 (neutral to annoyed) prior and after cognitive load. Higher scores indicate higher level of annoyance either prior to or after the cognitive load. Because increased cognitive demands may increase affective valence that impacts ToM performance, we calculated a rate of change score between the beginning and end of the cognitive load task to be used as a control.

Behavioural task measures

Affective theory of mind task

Affective theory of mind was assessed using the child version of the mind in the eyes task (Baron-Cohen et al., 2001), an adaption of the original mind in the eyes with child-level vocabulary (Baron-Cohen et al., 1997), where participants are presented with 28 trials with images of human eyes along with four options of what that person is feeling. Participants responded with the emotion they feel best represents the eyes presented. Of these trials, 11 involve basic emotions (e.g. happy, sad, scared, angry), and 17 involve complex emotions (e.g. nervousness, boredom, shame; Adolphs et al., 2002; Baron-Cohen et al., 1997). This task demonstrates test-retest reliability (Fernández-Abascal et al., 2013; Olderbak et al., 2015) suggesting learning effects are of minimal concern for the repeated instance of the task in our design. Consistent with a recent psychometric examination of the mind in the eye task (Olderbak et al., 2015), we calculated internal consistency using Omega (ω) with a tetrachoric correlation matrix using the "psych" package in r (Revelle, 2021). Using ω more accurately captures internal consistency particularly for behavioural measures given that the traditionally coefficient of alpha can underestimate internal consistency (Crutzen & Peters, 2017; Peters, 2014) particularly during behavioural tasks (Watkins, 2017). Each instance was found internally consistent at baseline for overall (ω = 0.77), basic (ω = 0.74), and complex (ω = 0.78); as well as time two for overall (ω = 0.84), basic (ω = 0.77), and complex (ω = 0.83). Correct responses were summed for each condition and each subscale so that higher scores indicate greater accuracy for affective theory of mind judgments.

Tax on cognitive control

Participants completed a version of the stop signal task, which is an important measure of cognitive control mechanisms involved in inhibitory processes (For review: Brockett et al., 2021) and has been used in prior studies to tax cognitive control in youth (Logan et al., 1997; Steinbeis, 2018). Participants were presented a go signal (blue squares) for 120 trials and 30 of those trials were followed by a stop signal (green triangles; inter-trial interval 3000 ms). Following Steinbeis (2018) protocol, participants were asked to hold their response to see if a stop signal follows the initial go signal. To maximally tax cognitive control for each participant, the stop signal delay increased or decreased by an increment of 50 ms per trial depending on whether the response was successfully inhibited or not (interstimulus interval range 50–1600 ms, starts at 150 ms and increases/decreases 50 ms if correct/incorrect). We recorded the maximum interstimulus delay reached to indicate the maximum cognitive load for each participant. Higher maximum cognitive load score indicates a higher duration of a cognitive load they can endure suggesting greater cognitive control. It is important to mention that this very protocol with this very task was used in prior work to tax cognitive control in youth (Steinbeis, 2018).

Additional variables and covariates

Careless respondents

Highly patterned responses to surveys and tasks indicate participants that responded carelessly. Careless participants were identified statistically using the "careless" package in r (Yentes & Wilhelm, 2018). We created a variable indicating the level of carelessness to be entered into the model to regress out variation due to carelessness. To determine respondent carelessness, we assessed (1) long-string: how long of a string of the same response the participant had (i.e. how long the participant pressed the same response each time; Johnson, 2005), (2) item-variability: the variability of response (i.e. how much participants responses varied from question to question with low variability suggesting carelessness; Dunn et al., 2018), and (3) even-odd: the extent to which even and odd responses were similar (e.g. level of consistency between even and odd responses with more consistency indicating carelessness; Johnson, 2005). This three-pronged approach was used to capture multiple sources of careless responding, which results in a continuous variable indicating the level of carelessness for each participant.

We used the median and median absolute deviation (MAD) to define those with careless responses outside a normal range. The MAD is more effective than other approaches (e.g. interquartile range and standard deviation) at detecting outliers as it is not strongly affected by outliers in the data, sample size, and is more robust (Leys et al., 2013). Preliminary investigation revealed variation in these scores; so we used a highly conservative criteria of MAD*3 (Leys et al., 2013) to ensure we were only identifying careless respondents. Specifically, we used a criterion of median – MAD*3 for item-variability of and median + MAD*3 for both long-string and even-odd. Regressing variation from careless respondents allows us to remove spurious results while retaining power by not removing these participants.

Identifying participants that did not receive a cognitive load

Similar to other studies using the stop signal task (e.g. Spunt et al., 2012), we statistically identified participants that did not receive a cognitive load to ensure the integrity of our data. To do this we used the logic that those who were both (1) a high outlier on no stop signal conditions (i.e. all trials were correct) and (2) a low outlier on responding to the stop signal condition (i.e. greater proportion of trials were incorrect) indicates a participant that was not responding to the task on both conditions and did not receive a cognitive load (i.e. not pressing a button for either condition). This metric was critical because this study is testing the impact of receiving a load; thus, we were not interested in using other metrics related to task performance. It is important to reiterate that participants had to meet both criteria to be considered for removal for not receiving a cognitive load. This logic and the use of accuracy to determine these participants is consistent with previous studies using the stop signal task (e.g. Spunt et al., 2012). Preliminary data investigation revealed most participants did well on the non-stop signal and many did well on the stop signal condition; so we choose a moderately low conservative criteria to detect outliers of median±2*MAD (Leys et al., 2013) to identify participants that met both conditions. We created a dichotomous variable indicating participants that met both criteria that were removed from the analysis. Removing these participants helps us to ensure we are measuring the impact of a cognitive load and not a spurious result due to task inattention.

Covariates

In all analyses we controlled for sex, age, race, careless respondents, and conduct problems; and, in analyses that examined the impact of cognitive load, we controlled for the change in affective rating from before until after the cognitive load task. Race may account for variation in identifying emotions in faces outside of one's racial category (Chiroro & Valentine, 1995), thus we controlled for race. We dichotomised race to indicate the primary racial category (White) and other races because (1) stimuli used in the aToM task were exclusively White faces, thus variation was expected to differ from White participants and, given the lack of sample diversity, (2) to have adequate representation of racial categories to account for this variation. The primary interest of the present study is to examine CU traits association with outcomes of interest; thus, we controlled for conduct problems in our analyses. Conduct problems are often comorbid with CU traits but are distinct and associate with different outcomes (e.g. Baskin-Sommers et al., 2015; Herpers et al., 2012; Hyde et al., 2015). Thus, to prevent conflating antisocial behaviour with the callous-unemotional dimension of interest, we used the conduct problem subscale of the SDQ as a covariate. But, to ensure there is no suppression effect (e.g. Hyde et al., 2016; Lozier et al., 2014), we also ran all models without controlling for conduct problems to assess suppression concerns. Because estimates did not change and no evidence of suppression effects were found, we only report on models that control for conduct problems.

Analysis

Assessing whether bias was introduced by removing participants

We assessed if any bias was introduced by excluding cases that did not receive a cognitive load from those included in the final analysis. We constructed a set of *t*-tests for continuous variables and chi-square tests for binary variables to see if the group we excluded was statistically different on demographics and modelled variables. To ensure effects were not due to sampling variability and differences in group sizes, these tests were bootstrapped using the "mKinfer" package (Kohl, 2020). Importantly, we only removed participants that met criteria for not receiving a cognitive load on analyses that included the cognitive load task.

Assumption checking

We assessed for assumptions of multicollinearity, normality of residuals, auto correlation, and linearity. We detected no violations to these assumptions, and we had no missing data in our sample. Thus, we designed our analytic approach without needing to account for non-normality, non-linear associations, or missing data.

Analytic approach

We conducted analyses to test CU traits association with (1) aToM (basic and complex), (2) maximum cognitive load achieved, and (3) the impact of taxing cognitive control on aToM. For the first two analyses, we fit a path model using the "lavaan" package (Rosseel, 2012), which provides two advantages for statistical inference. First, this allowed us to estimate multiple outcome variables simultaneously in one model that increases power while decreasing error introduced by estimating multiple models. Second, this approach allowed us to model the correlation between related outcomes and estimate model parameters on the unique variance of each outcome, which improves the inference of estimated parameters. These path models were estimated using maximum likelihood estimation. We conducted an analysis of CU traits on basic and complex ToM simultaneously. Then, follow up analyses were conducted to determine if a particular CU trait subscale drove associations. For all analyses we obtained bias corrected bootstrapped confidence intervals for each parameter using 5000 resamples of the data. Moreover, to test the impact of sex on each of these associations we tested sex as a moderator, but none of these results were significant and descriptions of the analyses and results can be found in supplemental material (See Supplemental Tables 7–9).

To test the impact of a cognitive load on affective ToM as a function of CU traits, we used the "lme4" package (Bates et al., 2014) to estimate a random effects model accounting for repeated measures of affective theory of mind (before and after a cognitive load) as a function of CU traits. We included random effects for individuals and fixed effects for time, CU traits, and their interaction. We orthogonalized interaction terms from the model using the residual centring approach by Little et al. (2006), which retains model assumptions of residual independence while allowing us to interpret interaction and direct paths in one model (Little et al., 2006). Our approach involved first modelling total CU traits as the independent variable then we conducted follow up analyses to examine (1) if a subscale may account for significant associations and (2) if a specific level of cognitive load impacted changes in aToM as a function of CU traits. Prior to interpreting, we assessed if adding random effects improved model estimation using a likelihood ratio test to compare a fixed effects regression with the random effects model. We used "lmerTest" (Kuznetsova et al., 2019) to obtain correct p values for the parameters of the random effects model and "lmersampler" (Loy Adam et al., 2021) to obtain bootstrapped confidence intervals for all parameters with 5000 resamples. Additionally, we estimated variance accounted for by each independent variable (R^2) using the "r2glmm" package (Jaeger, 2017). We choose mixed effects modelling for our repeated measure analysis because it addresses common biases due to omitted variables (Bascle, 2008; Ghose, 2019; Phillips & Hansen, 1990; Stone & Rose, 2011), improves generalizability and reproducibility of results (Yarkoni, 2020), and overcomes many barriers of traditional analyses with repeated measures data (e.g. ANOVA; Quené & van den Bergh, 2004) by modelling individual variation, thus bolstering statistical inferences on repeated measure outcome effects. Finally, figures of these statistical analyses filtered out variation to accurately represent the analyses.

Results

Variable descriptives

CU Traits and Conduct Problem Distribution. The current sample had distributions of ICU (30.23 ± 6.68) and SDQ conduct (1.51 ± 1.71) scores commensurate with other community samples (Byrd et al., 2013; Essau et al., 2006) and population norms respectively (https://sdqinfo.org/norms/USNorm1.pdf).

No cognitive load

We identified nine participants that met criteria for not receiving a cognitive load. These participants were removed from analyses that were related to the stop signal task. Specifically, we removed these participants from analyses involving CU traits association with maximum cognitive load and the impact of a cognitive load on aToM.

Assessing bias from removing participants with no cognitive load

Results revealed that participants removed from the analysis due to not receiving a cognitive load were not significantly different on demographics of race, age, or sex, nor were there significant differences in callous-unemotional traits, outcome variables or control variables planned in the formal analysis test.

Lower baseline complex toM associated with greater CU traits

Higher CU traits negatively associated with complex ToM ($\beta = -0.148(0.\ 045)$, $p = 0.001$, $R^2 = 0.166$; Table 2), but did not significantly associate with basic ToM ($\beta = 0.\ 001(0.\ 001)$, $p = 0.991$, $R^2 = 0.048$; Table 2; Figure 1). Age, race, sex, conduct problems, and careless responses did not significantly account for additional variance in the outcome variables. Follow up analyses suggests the callousness dimension drives this association with complex aToM (Supplementary Table 1).

Lower cognitive control associated with greater CU traits

Higher CU traits associated with lower maximum cognitive load ($\beta = -28.704(11.25)$, $p = 0.010$, $R^2 = 0.162$, Table 3, Figure 2). Age, race, sex, conduct problems, and careless responses did not significantly account for additional variance in the outcome variable. Follow up analyses suggest that the uncaring subscale drives this association (Supplementary Table 3).

Complex toM decrements after a cognitive load associated with CU traits

Greater decrements in overall ToM accuracy associated with higher CU traits ($\beta = -0.127(0.056)$, $p = 0.026$) with a significant interaction between timepoint and CU traits ($\beta = -0.100(0.047)$, $p = 0.035$; Table 4, Figure 3). Follow up analyses revealed this interaction effect was primarily driven by the unemotional subscale ($\beta = -0.386(0.144)$, $p = 0.009$; Supplementary Table 3, Supplementary Figure 1). Age, race, sex, annoyance, and conduct problems did not significantly account for additional variance in the outcome variable. Moreover, there was no significant association with basic emotions (Supplementary Tables 4 and 5).

Level of cognitive load that impacts complex affective theory of mind at higher levels of CU traits

Greater decrements in aToM significantly associated with cognitive loads of 200 ms ($\beta = -1.920$ (0.60), $p = 0.003$, $R^2 = 0.034$) and 400 ms ($\beta = -0.813(0.056)$, $p = 0.025$, $R^2 = 0.018$) in those higher in CU traits. However, a load of 200 ms accounted for more variance than a load of 400 ms ($R^2 = 0.034$ vs. $R^2 = 0.018$ [respectively], Figure 4, Supplementary Table 6).

Discussion

Results reveal that youth with higher CU traits have impairments in complex aToM and cognitive control, and that placing additional demands on cognitive control results in added decrements in complex aToM. These results extend previous work by evidencing cognitive control as a critical component of aToM impairments associated with CU traits. Importantly, this effect was observed at the lowest levels of response inhibition indicating an important sensitivity

Table 2. Results of theory of mind as a function of callous-unemotional traits.

	Std β	Unstd β	SE	z-value	p-value	Bootstrapped CI_{95} Lower	Upper
Complex ~ (R^2 = 0.166)							
CU traits	−0.436	−0.148*	0.045	−3.283	0.001	−0.241	−0.061
Male	−0.200	−0.903	0.509	−1.773	0.076	−1.942	0.078
Age	0.040	0.121	0.337	0.357	0.721	−0.530	0.788
White	−0.079	−0.385	0.545	−0.706	0.480	−1.506	0.663
Conduct	0.245	0.325	0.197	1.650	0.099	−0.060	0.710
Careless	−0.070	−0.404	0.568	−0.711	0.477	−1.482	0.772
Basic ~ (R^2 = 0.048)							
CU traits	0.000	0.000	0.036	0.000	0.991	−0.075	0.070
Male	−0.045	−0.167	0.399	−0.418	0.676	−0.934	0.646
Age	0.030	0.074	0.292	0.255	0.799	−0.515	0.613
White	0.020	0.081	0.459	0.176	0.861	−0.807	1.012
Conduct	0.185	−0.200	0.178	−1.123	0.261	−0.567	0.139
Careless	−0.123	−0.584	0.487	−1.199	0.231	−1.530	0.381

Note: $n = 81$; Bootstrapped confidence intervals are bias corrected with 5000 resamples.
*$p < 0.05$.

to cognitive demands at higher levels of CU traits. This novel finding sets the stage for defining an important mechanism underlying core impairments in CU traits.

Less complex affective theory of mind associates with callous-unemotional traits

Replicating findings by Sharp et al. (2015), we found that CU traits did not associate with basic aToM; but higher CU traits associated with less complex aToM accuracy. Although Sharp et al. (2015) speculated this effect could be due to emotion recognition deficit through affective impairments related to amygdala dysfunction, we assert that cognitive control may be the source of impairment. Our assertion is derived from research that complex emotions require greater cognitive demands (Yates et al., 2010), that those with CU traits demonstrate cognitive control impairments (Gluckman et al., 2016), and that both adults with psychopathy (Baskin-Sommers et al., 2013; Sadeh et al., 2013) and adolescents with CU traits (Sharp et al., 2015) demonstrate difficulty with complex emotions but not under less demanding basic emotions. Given that cognitive control modulates aToM (for reviews: Mahy et al., 2014; Wade et al., 2018), it is plausible that cognitive resources that are adequate for basic aToM would fail under the higher demands of complex aToM (Tillem et al., 2020). This result suggests that affective stimuli in less demanding basic contexts are not affected but, at higher CU traits, aToM is more difficult for complex emotions that require higher cognitive demands.

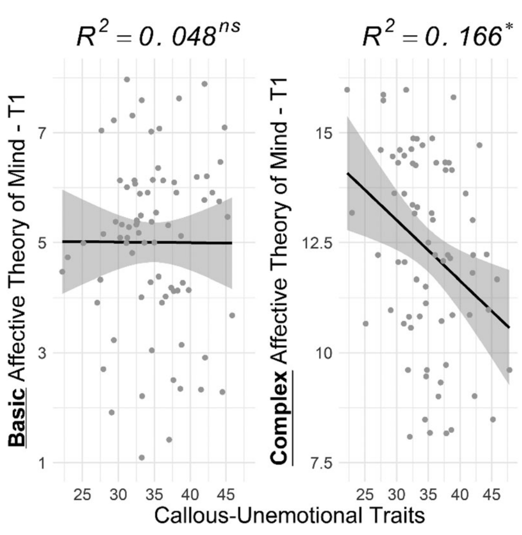

Figure 1. Depicting callous-unemotional traits association with basic and complex affective theory of mind at baseline only. Note: plotted after adjusting for sex, age, race, conduct, and careless responses.

Less cognitive control associates with higher callous-unemotional traits

Higher CU traits associated with lower levels of maximum cognitive load that a participant withstood. The task adaptively increased or decreased the interstimulus interval to prolong the amount of inhibition duration as a measure of cognitive control. Higher levels of CU traits associated with lower levels of cognitive control. This effect has been demonstrated during a conflict adaption paradigm with peripheral cues to the focus of attention where those higher in CU traits demonstrated less cognitive control (Gluckman et al., 2016). The present study extended this previous

Table 3. Results of maximum cognitive load as a function of callous-unemotional traits.

	Std β	Unstd β	SE	z-value	p-value	Bootstrapped CI_{95}	
						Lower	Upper
Max load ∼ (R^2 = 0.162)							
CU traits	−0.318	−28.704*	11.249	−2.552	0.011	−52.519	−3.072
Male	−0.147	−171.901	130.104	−1.321	0.186	−427.660	108.428
Age	0.135	105.312	86.868	1.212	0.225	−86.821	270.101
White	−0.221	−282.270	145.145	−1.945	0.052	−576.690	−18.089
Conduct	0.160	60.187	50.356	1.195	0.232	−63.720	176.352
Careless	−0.122	−197.053	187.065	−1.053	0.292	−605.908	251.494

Note: $n = 72$; removed 9 participants for not responding during Inhibitory processing task.
Bootstrapped confidence intervals are bias corrected with 5000 resamples.
*$p < 0.05$.

result by revealing that, even when focusing attention on one location central to the task, the capacity to sustain cognitive control over a period of time was significantly less at higher CU traits. This has significant implications for the capacity to withstand daily cognitive demands which may impact a variety of cognitive and social processes in those with higher CU traits – including aToM. Overall, this finding suggests that those higher in CU traits have a greater sensitivity to cognitive demands. Thus, it is plausible to further probe how placing additional cognitive demands on cognitive control may impact aToM.

Taxing cognitive control negatively impacts affective theory of mind

Taxing cognitive control did not impact basic aToM but resulted in greater decrements in complex aToM at higher levels of CU traits. This suggests the cognitive resources required for basic aToM remains intact even under higher cognitive demands but that these resources fail for complex aToM, which already have inherent additional demands required to process. Importantly this effect was observed even after controlling attention on one location and orientated goal directed attention by instructing participants to engage in the aToM task. Thus, the present study extends previous research on attentional systems related to affect processing by demonstrating that the level of cognitive load is an additional and modifiable process that impacts complex aToM. Greater difficulty with complex aToM is thought to explain CU traits association with aggressive criminal acts (Tillem et al., 2020). Given that the social landscape is more often complex than basic, which requires processing higher levels

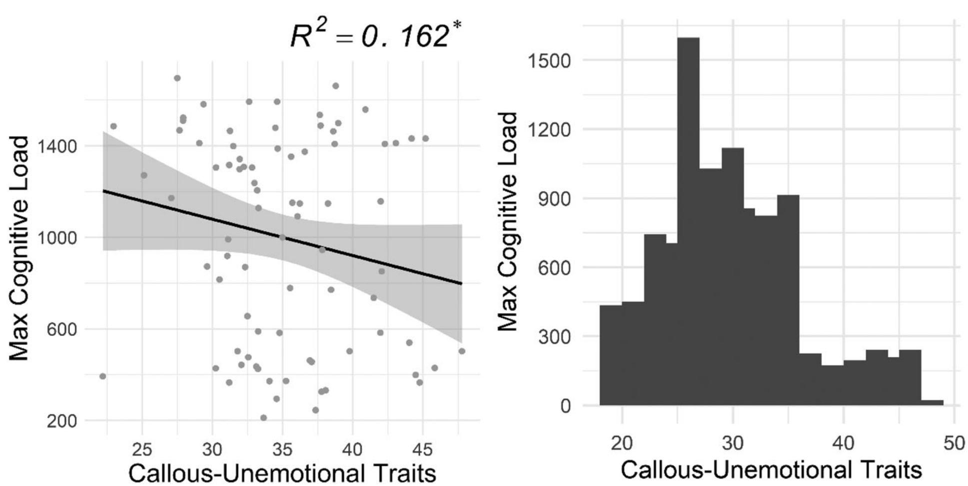

Figure 2. Depicting callous-unemotional traits association with maximum cognitive load. The scatterplot on the left indicates the level of cognitive load as s function of callous-unemotional traits. The plot on the right depicts the distribution of maximum cognitive load across different levels of callous-unemotional traits. Note: scatterplot is representing datapoints after adjusting for sex, age, race, conduct, and careless responses.

Table 4. Mixed effects model results for total callous-unemotional traits.

						Bootstrapped CI_{95}	
Fixed effects	Unstd β	SE	*t*-value	*p*-value	R^2%	Lower	Upper
Intercept	13.720*	5.466	2.510	0.015		3.404	24.037
CU Traits	−0.127*	0.056	−2.273	0.026	6%	−0.232	−0.021
Time	−0.500	0.286	−1.747	0.085	1%	−1.061	0.061
CU * Time[a]	−0.100*	0.047	−2.145	0.035	2%	−0.191	−0.009
Annoyance	0.014	0.009	1.517	0.134	3%	−0.003	0.031
Male	−0.899	0.576	−1.559	0.124	3%	−1.987	0.189
Age	0.300	0.394	0.762	0.449	1%	−0.443	1.043
White	0.059	0.219	0.271	0.787	1%	−0.354	0.473
Conduct	−0.553	0.655	−0.844	0.402	0.1%	−1.789	0.684
Random effects (co-variances)							
Individual intercept	4.186	2.046				1.484	2.413
Residual	2.949	1.717				1.450	2.013

Note: $n = 72$; Bootstrapped confidence intervals are bias corrected with 5000 resamples.
*$p < 0.05$.
All *p*-values are two-tailed.
Time is coded 0 = baseline ToM and 2 = second ToM after a cognitive load.
[a]Orthogonalized from the model using residualized centring approach.
Marginal $R^2 = 0.15$ Conditional $R^2 = 0.65$.

of context (Barrett et al., 2011) and, subsequently, greater cognitive resources to process (Yates et al., 2010), it is plausible that this finding is highly relevant for real world contexts.

Follow up analyses revealed that a small cognitive load could impact complex aToM at higher levels of CU traits. This demonstrates a vulnerability in resources for cognitive control necessary for aToM. This deficit has been demonstrated in previous research (Gluckman et al., 2016), and its impact on aToM revealed here is consistent with previous research demonstrating cognitive control modulates aToM (for reviews: Mahy et al., 2014; Wade et al., 2018); thus, our current finding supports the assertion that impairments in complex aToM are partially explained by cognitive control impairments. In the context of the expected value of control (EVC) model of cognitive control, this would suggest that resources for cognitive control necessary for complex aToM is more costly at higher levels of CU

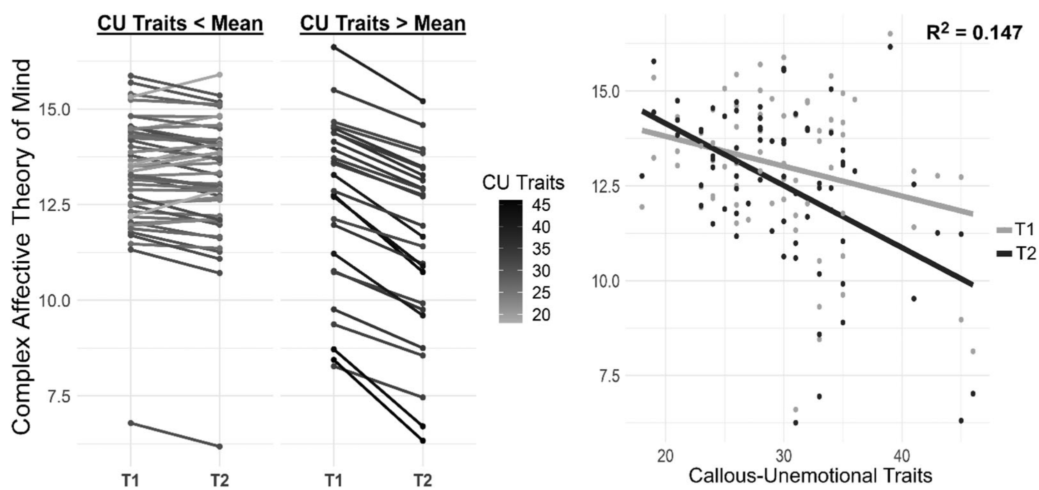

Figure 3. Depiction of changes in complex affective theory of mind after a cognitive load as a function of total callous-unemotional traits. The figure on the left depicts each individual's random trajectory from first instance of the ToM task to the second instance after a cognitive load as a function of callous-unemotional traits. The figure on the right depicts the mean change in complex affective theory of mind as a function of callous-unemotional traits prior to (T1) and after (T2) a cognitive load. Note: in the figure on the left, participants are separated by mean callous-unemotional traits to avoid over plotting and darker line = greater callous-unemotional traits. Note: in the figure on the right the lighter line indicates the first instance of the ToM task whereas the black line indicates the second instance of the ToM task after a cognitive load.

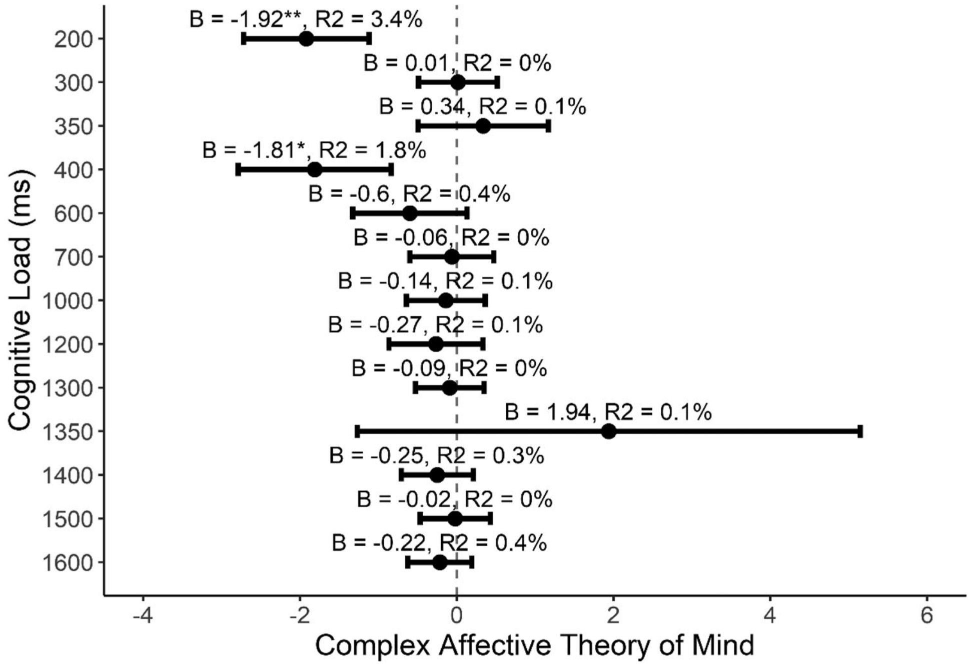

Figure 4. Depiction of random effects model betas and confidence intervals predicting changes in complex affective theory of mind at different levels of cognitive load interacting with time and callous-unemotional traits. Note: the dotted line at 0 is to aid identifying which levels of cognitive load can be statistically distinguished 0 for significance.

traits and that additional demands on cognitive control exacerbate existing limitations on allocating cognitive resources. Overall, this study provides evidence that cognitive control can be modified in youth with CU traits; therefore, it is plausible that interventions elevating cognitive control may improve aToM in youth with CU traits.

Limitations

The previous results must be interpreted under some limitations. First, all study participants were exposed to the same conditions, and we could not compare effects observed in a control group that did not receive the cognitive load. It is possible that, given the length of the task, that fatigue may partially account for taxing effects. However, we find this unlikely given that (1) prior work demonstrates test-retest reliability (Fernández-Abascal et al., 2013) and (2) that we observed consistency across instances in the aToM task in basic but changes in complex aToM. If fatigue were driving the results we would expect a decrement in basic along with drops in complex aToM performance, but this was not the case and supports the notion that without a load we would not have seen a statistically significant difference in complex aToM and that our study was testing cognitive load. Additionally, it is plausible that low motivation may account for effects; however, to mitigate these effects we statistically identified and controlled for those that did not participate in the cognitive load condition or with careless responses. Future studies could build on this result and parse effects of taxing by including a control condition where participants do not receive a cognitive load for between condition comparisons or employ a dual task design to test within subject effects and further parse within individual differences. Second, it is unclear what precise cognitive process or combination of processes are being taxed with the stop-signal task, given that no cognitive task is pure and often include other cognitive processes to support the measured cognitive function (Brockett et al., 2021). Future studies could parse different cognitive functions for specific targets. An alternative design that could use a dual-task design to capture within subject effects on differences in load. Third, we did not assess for IQ. IQ has a mixed relationship with psychopathic traits (for review: Johansson & Kerr, 2005) but does associate with the mind in the eyes task specifically (for meta-analysis:

Baker et al., 2014); however, given that it is unlikely it changed in the period of time it took to complete the task – IQ was plausibly stable and did not impact the change in complex aToM observed here. Future studies could examine IQ to further examine this. Fourth, ADHD is highly comorbid with externalising symptoms, which may account for difficulties in executive functioning. While we did not collect this information in the present study – future studies could build on these initial findings by parsing out variation attributed to ADHD symptomology. Regarding basic aToM, given most participants did well at identifying basic emotions, there may have been a ceiling effect making identification of differences difficult with the current analytic method. We must also recognise that we cannot rule out practice effects due to the repeat of the aToM task; however, we find this highly unlikely because, where we would expect practice effects to result in a performance improvement, basic theory of mind stayed consistent and complex theory of mind demonstrated a decrement after a cognitive load as a function of CU traits. If practice effects were in effect, we would expect improvements in either basic or complex theory of mind. Fifth, it is important to point out that after removing participants for not participating in the study, we had 72 participants when 81 was required for 80% power to detect effects between CU traits and aToM. This means it is possible that we could not detect some effects, and it is important to recognise future studies require larger sample sizes to ensure all significant effects can be detected. Finally, this study was conducted completely online, and participants completed the study in different environments. To mitigate spurious findings, we detected participants that had careless responses or likely did not receive a cognitive load and we conducted a statistical analysis that accounted for individual variation. However, future studies could build on this study by having participants complete the study in a controlled environment for all participants.

Conclusions

The present study identifies a heightened sensitivity to cognitive demands on cognitive control in youth with higher CU traits that negatively impacts complex aToM. The novel contribution of this study is that this finding held even after mitigating attentional components by having all task stimuli on one location and providing explicit instructions to establish goal-oriented attention to the task. This approach isolates cognitive resources for cognitive control in relation to aToM and identifies a novel mechanism for understanding complex aToM impairments in youth with CU traits. Impairments in aToM for complex emotions may explain how youth with CU traits engage in harmful and criminal behaviour (Tillem et al., 2020); thus, understanding how to increase cognitive control in these youth may bolster aToM and attenuate antisocial behaviour. The main conclusions are supported by the available literature but extend it to reveal a novel component of cognitive control is modifiable and it impacts how youth with CU traits infer other's emotions. This novel finding opens a path of future investigations to improve our mechanistic understanding of core CU trait impairments, which may indicate where to intervene to help these youth. Modelling cognitive control in relation to complex aToM impairments using a randomised control design in an fMRI may help identify a mechanism to target and help inform the development of new interventions to address persistent antisocial behaviour in youth with CU traits.

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No potential conflict of interest was reported by the authors.

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Data availability statement

Data are available upon request to qualified investigators, so long as the proposed work aligns with the approved study aims as consented to by study subjects. Requests may be sent to the corresponding author, Dr. Drew E. Winters.

ORCID

Drew E. Winters http://orcid.org/0000-0002-0701-9658
Joseph T. Sakai http://orcid.org/0000-0003-1600-6100

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