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ORIGINAL ARTICLE

Cognitive Control Difficulties Differentiate Callous-Unemotional Traits from Conduct Problems: A Pre-Registered Double-Blind Randomized Controlled Trial Analysis

Drew E. Winters[1] · Juliet Spitz[1] · Kristen Raymond[1] · Crystal Natvig[1] · Rebecca Waller[2] · Susan K. Mikulich-Gilbertson[1] · Joseph P. Schacht[1] · Joseph T. Sakai[1]

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Abstract

Cognition's role in youth antisocial phenotypes, particularly callous-unemotional (CU) traits (e.g., lack of remorse, guilt, and empathy) and conduct problems (CP; e.g., disruptive and aggressive behaviors), remains debated. Recent findings suggest the need to distinguish inhibitory processes, as selective control (inhibiting a prepotent response for an alternative) rather than passive control (non-response action restraint) has been linked, independent of CP, to affective deficits in CU traits. However, it is not known whether CU traits relate to a general difficulty with cognitive demands or a specific impairment in selective control. The present study tested whether CU traits were differentially related to passive versus selective control, accounting for CP. Using a randomized parallel-arm trial with test and control groups, data from 85 participants (aged 12–14, 47% female) were analyzed with mixed effects models to account for individual variance. Results indicated that CU traits were associated with better passive control but worse selective control, while CP showed no significant effects when CU traits were included. This pattern was consistent across accuracy, reaction times, and contrasts between trial types (e.g., selective > passive). Further analyses suggested that CU traits were linked to a rigid cognitive style specifically during selective control trials. These findings highlight a selective control deficit unique to CU traits, distinguishing them from CP. Moreover, evidence of a rigid cognitive strategy aligns with research on adult psychopathy, suggesting potential difficulties with cognitive resource allocation. Thus, selective control may be an important feature for understanding antisocial etiological pathways.

Keywords Callous-unemotional traits · Conduct · Adolescence · Cognitive control · Selective control

Introduction

Cognitive inhibition is critical for understanding the etiology of antisocial behavior. However, this understanding is obscured by nuanced and conflicting findings regarding how different cognitive processes influence distinct antisocial phenotypes of conduct problems (CP; i.e., antisocial patterns of disruptive and aggressive behaviors linked with antisocial deficits in adult psychopathy) and callous-unemotional (CU) traits (i.e., lack of prosocial emotions of guilt, remorse, and empathy linked with affective deficits in adult psychopathy [1]. Nuances across the literature may reflect arguments in the review by Baskin-Sommers et al. [2], with broader cognitive deficits whereas CU traits associate with less pronounced cognitive, but more specific deficits, in inhibition. Inhibition is a broad term [3] and the mixed findings may be improved by differentiating between tasks requiring a passive non-response where one restrains an action (i.e., passive control) or an active response involving the recognition of a stimulus and responding alternatively from prepotent response (i.e., selective control [4]. Selective control is particularly important for understanding antisocial phenotypes because of its central role in affective processing [5], that is thought to be critical for understanding antisocial

✉ Drew E. Winters
drew.winters@cuanschutz.edu

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

[2] Department of Psychology, University of Pennsylvania, Philadelphia, PA, USA

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pathways to CU traits and CP [1, 6]. Thus, there is need for refined cognitive models that differentiate between specific functions in antisocial phenotypes.

Efforts to Improve Specificity with Latent Modeling and Limitations

To improve specificity, prior studies have applied latent modeling to extract cognitive processes across multiple tasks [7]. Applying this approach revealed that CU traits distinctly associated with lower inhibition in both adults [8] and early adolescents [9]. These results implicate inhibitory deficits unique to CU traits; however, although assessing inhibition across multiple tasks addresses measurement error, a latent modeling approach can only represent a general inhibitory processes because it removes specificity on relevant task-specific features that could be targeted to improve outcomes (e.g., latent models of disorders [10, 11]. Therefore, improving antisocial etiological models requires testing specific cognitive functions, such as selective and passive control.

Passive Control Tasks and Limitations

Inhibition paradigms, such as the stop signal and go/no-go tasks, require a lower effort passive non-response, or passive control, that may not be as relevant for distinguishing CP and CU traits. The traditional stop signal task involves canceling a prepotent response by not responding whereas the go/no-go involves restraint to specific stimuli by restraining action by not responding [12]. These tasks are less demanding as they do not show inter-trial demands that impact subsequent task performance [13], which may explain their mixed associations with antisocial phenotypes. For the traditional stop signal task, one study found adolescents with CU traits had faster reaction times over those with CP or ADHD [14], whereas another study on adolescents report no significant associations for either phenotype [15]. For the go/no-go task, one study found that the association between CP and go/no-go performance was moderated by CU traits such that it was negative at low CU traits but positive at high CU traits [15], whereas another found CP (but not CU traits) was linked to worse performance on a go/no-go task [16]. A meta-analysis across both stop signal and go/no-go tasks found significantly worse passive control for both CU traits and CP, with CP having a stronger link [17]. These conflicting findings are plausibly due to the lower effort required by these passive control tasks [13] given that control processes vary as a function of how much effort is required in relation to the availability of resources to meet the demands of the task [18].

Cognitive Paradigms Requiring Higher Cognitive Demands

Paradigms requiring higher cognitive demands can offer greater specificity by measuring phenotype-relevant functions. Higher demanding tasks measure more demanding processes of detecting unexpected stimuli (e.g., Oddball) and suppressing conflict interferences (e.g., Stroop, flanker). Conflict in the Stroop task involves incongruence between a word and the color of its letters screen [19], whereas conflict in the flanker involves spatially distributed distractors [20]. For flanker task performance, one study found that both CP and CU traits were associated with worse performance relative to typically developing children, suggesting that interference suppression may be a general marker of antisocial behavior rather than specific to one phenotype [14]. For the traditional Strop task (with stimuli centered on the screen), CP was linked with poorer performance [21] and aberrant brain responses [22] while another found that CU traits associated with better traditional Stroop task performance [23]. The flanker and Stroop findings together suggest that CU trait inhibitory deficits were detected (although not distinguished) when the flanker task required selective control.

Selective control processes were added to a Stroop task by modifying it to incorporate distractor stimuli, which revealed that adolescents with high CU traits had worse performance, whereas those with CP performed better [24]. CU traits were also uniquely linked to poorer performance and greater cognitive demands relative to controls in adults during the oddball task [25, 26]. These results suggest that CU traits may be especially vulnerable to deficits in selective control under higher cognitive demands. Importantly, because CU traits are differentiated from CP by specific affective processing deficits [1], tasks measuring selective control (which is critical for processing affective information) may help pinpoint cognitive limitations unique to CU traits.

Study Rationale and Hypotheses

Building on these findings, the current study sought to contrast passive and selective control using a selective stimulus stop signal task (SSSST) in an adolescent sample. This design aims to determine whether the cognitive deficits linked to CU traits—particularly those involving selective control—persist independently of affective processing. Supportive evidence for this theory would first show CU traits are distinctly associated with cognitive limitations in processing affective information (i.e., affect differentiates CU traits from CP [1], which has been done in prior work (e.g. [6, 27]. Second, evidence would need to link CU traits in distinct ways from CP to worse cognitive performance

beyond affect processing. Given that, as outlined above, CU traits associates with improved performance during CU passive inhibition tasks but worse performance during selective control tasks, the preregistered hypotheses were: (H1) CU traits would associate with lower reaction times during selective control trials (H1.1) and lower stop signal reaction times (H1.2); (H2) CP would associate with worse reaction times during passive control trials (H2.1) and shorter stop signal delay (H2.2); and (3) CU traits would moderate associations between CP and passive inhibition trials (H3.1) and selective control trials (H3.2), such that CP would relate to worse performance for those lower on CU traits. Supplemental analyses included a measure incorporating accuracy and reaction time in one metric (balanced integration score [28], and a measure to examine the cognitive processing strategy (entropy [29, 30] as a way to test a feature of adult psychopathy that is rarely tested in youth (e.g., [31, 32].

Methods

Power Analyses

Two a priori power analyses were conducted. The first used G*Power [33] to identify the sample size necessary an omnibus test between conditions using effects based on [32]. This test determined at least 72 participants were needed for 80% power to compare groups. The second used the pwr package [34] with the sample size determined by the first test to identify the lowest detectable beta value estimates. This test determined there was 90% power to reliably detect a $\beta = 0.001$.

Recruitment, Randomization and Blinding, and Study Procedures

Data collection, randomization, blinding, and study procedures as preregistered (https://doi.org/10.17605/OSF.IO/BHWEU) and outlined in prior work [6] can be found in the supplemental methods. Broadly, community participants were randomized with a permuted block randomization scheme into test and control groups (recruited for and randomized by equal split by severity of CU trait and sex), with high CU Traits indicated by who qualified for the low prosocial emotion specifier with the method validated by Kimonis et al. [35] rating 9-items from the self-report Inventory of Callous-Unemotional Traits. Task instructions for control participants were to press the spacebar regardless of the trial (i.e., did not inhibit) whereas test participants were instructed to complete each trial as instructed, requiring inhibition (details on task and trials can be under Behavioral Measure). Participants were excluded from data collection if their IQ score was <70 (as measured by the Shipley-II; Zachary & Shipley [36], or they were at risk for autism (score $>=13$ on the Autism Spectrum Screening Questionnaire [37].

Transparency and Openness

The present preregistered analysis (https://osf.io/xsb85) uses a preregistered data collection (https://doi.org/10.17605/OSF.IO/BHWEU) and extends it by focusing on specificit y of cognitive functions in the selective stimulus stop signal task (SSST). Code for analysis can be is posted publicly (https://github.com/drewwint/pub_sssst_rct). There are no deviations from the primary analyses to report.

Sample

Supplemental Fig. 1 depicts reasons for exclusion/removal; 85 early adolescents (ages 12–14 ± 0.85) are included for analysis. This sample had a mean IQ of 94.84 (SD = 17.02), was balanced on sex (female 47%) and was predominately White (White 67%, Asian 12%, Mixed Race 8%, Black 7%, Hispanic 5%, American Indian 1%). The proportions of phenotypes (CU, CP, ADHD, Internalizing) were not significantly different by group (Supplemental Table 1). Sample demographics can be found in Table 1.

Self-Report Measures

The Inventory of Callous-Unemotional Traits [38], Sample $\Omega = 0.861$) is a 24-item measure of CU traits. This measure asks participants to rate statements like "I do not care who I hurt to get what I want" on a Likert scale ranging from 0 ("not true at all") to 3 ("definitely true"), with higher scores indicating greater levels of CU traits. Following previous research [35], we excluded two items from the ICU due to poor psychometric properties before calculating the total score used for analysis.

The Strengths and Difficulties Questionnaire [39, 40], total score sample $\Omega = 0.910$) was used to assess mental health symptoms. A total of 25-items were used from respective subscales to assess: conduct problems ($\Omega = 0.770$), ADHD ($\Omega = 0.847$), and internalizing symptoms ($\Omega = 0.779$). During this measure, participants rate items like "I take things that are not mine from home, school, or elsewhere" on a scale from 0 ("Not True") to 2 ("Certainly True"), with higher scores reflecting more severe symptoms in the respective domain.

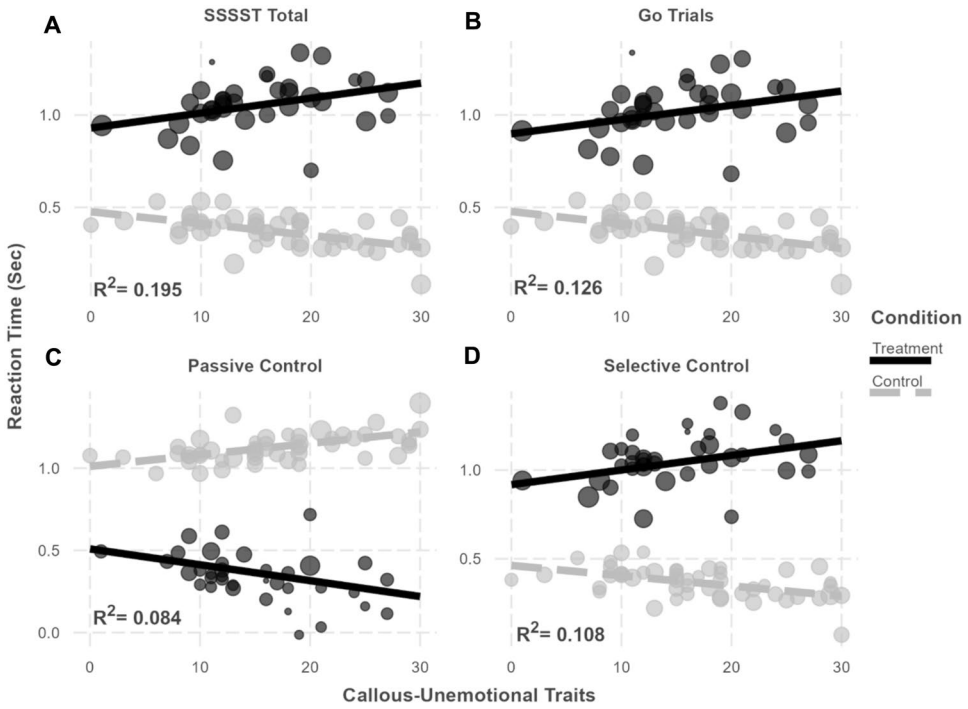

Fig. 1 Depicting the relationship between callous-unemotional traits and reaction time by trial type and treatment condition. (**A**) total Selective Stimulus Stop Signal Task (SSSST), (**B**) Go trials, (**C**) Passive control trials, (**D**) Selective control trials

Behavioral Measure

Stimulus Selective Stop Signal Task [4]

The SSSST is a modified stop-signal task that combines response inhibition and selection. It includes three trial types: (1) go trials (60%), where participants press the spacebar when shown a single downward arrow; (2) passive inhibit trials (20%), where participants do not respond when the arrow is surrounded by a green square; and (3) stop and select trials (20%), where participants press 'k' when the arrow is surrounded by a red diamond. The "stop and select" trials require active inhibitory responses driven by stimulus attention [41], offering a more cognitively demanding task than passive non-responses. Each trial started with presentation of a cross at the center of the screen and an intertrial interval with a jittered mean of 1000ms (between 500-1500ms). The delay between downward arrow (go) and inhibit signals (either green square or red diamond around arrow) was on a staircase that was adaptive to participants' responses. The delay started at 300ms and increased 50ms if participants responded to an inhibit trial correctly or decreased 50ms if they responded incorrectly. The stop signal delay minimum was 50ms and maximum was 1,100ms. For each trial, a participant response ended the trial with a max trial length of 1250ms.

This design addresses limitations of purely passive inhibition trials, which impose minimal challenges to participants [13]. Additionally, individuals with elevated CU traits demonstrate specific impairments in selective inhibition under such conditions [24]. By engaging both response inhibition and selection, the SSSST captures key components of cognitive control [42] that allow for the study of passive and active selective cognitive control for a more nuanced investigation into cognitive control and CU traits (see Task Schematic in Supplemental Fig. 2).

Calculated measures

Careless Responses. Participants with patterned responses indicating a lower good faith participation in completing self-report measures were identified using the 'careless' package [43]. A three-pronged approach was used to identify (1) long string, (2) response variability, and (3) even-odd in their responses. Participants outside the median * 3 median absolute deviation were indicated as having higher than normal patterns in their responses (for details see supplemental methods or [44]; as used in prior work: e.g., [6, 27]. This metric was used as a control in subsequent analyses to improve estimation of phenotypic inferences in relation to the behavioral task. Consistent with conceptual expectations, preliminary checks including correlation of residuals did not detect this metric to introduce bias as a collider.

Contrasts between SSSST conditions. Contrast values were derived using the following formula:

$$C1 > C2\ Contrast = \frac{C1-C2}{(C1+C2)/2}(\text{ where C=condition})$$

for a regularized percentage change score from the trial being contrasted from.

Table 1 Sample descriptives

		Group				Correlation Table								
		Total Sample	Control ($n = 49$)	Test ($n = 36$)	*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	Careless 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									

Stop signal reaction time. The stop signal reaction time (SSRT) was derived using the integration adaptive method implemented in the 'SSRTcalc' r package [45].

Timeseries reverse coding for passive inhibition trials. Successful passive inhibition trials involve a passive non-response and subsequent longer timeseries indicating a greater degree of success. Because short reaction times for go and selective control trials indicate a greater degree of success on those trials, the timeseries for passive inhibition trials were reverse coded to have a commensurate interpretation with the go and selective control trials.

Balanced integration score. We added a tertiary and supplemental analysis with a balanced integration score because it has been shown to control the speed-accuracy trade off while retaining the "true effects" of the task while improving reliability over reaction time alone [28, 46]. Thus, we added this to supplement results from primary analyses. This metric subtracts the standardized reaction time from accuracy in the following formula

$$BIS = Accuracy\left(\frac{x-\mu}{\sigma}\right) - Reaction\,Time\left(\frac{x-\mu}{\sigma}\right)$$

. Higher values are interpreted as better performance on that trial whereas lower values indicate worse performance on that trial.

Entropy. Sample entropy was derived using the r package 'infotheo' [47] to quantitate the level of randomness to the reaction times for the SSSST. With this metric, higher entropy (high randomness) indicates cognitive flexibility and higher effort used whereas lower entropy (low randomness) indicates both cognitive rigidity and lower effort used for that cognitive function [29, 30].

Analyses

Preliminary data checks. Successful randomization was evidenced by comparing groups using independent t tests and chi-square tests. Quantitative variables were evaluated for approximate normality and associations between them with correlation. Further all model parameters were evaluated for additivity, multicollinearity, residual normality, and autocorrelation with no violations to report.

Analytic approach. As preregistered (https://doi.org/10.17605/OSF.IO/BHWEU), linear regression was used to test the impact of group (control or test) interacting with CP and CU traits on SSSST trial reaction times and trial contrasts. The analysis on SSRT and max stop signal delay was conducted only on participants in the test condition as these metrics only have meaning in the test condition. Secondary analysis included associations and contrasts with accuracy as well as sample entropy. Entropy measures the consistency in the task timeseries as a measure of cognitive flexibility (higher entropy) or cognitive rigidity (lower entropy) with

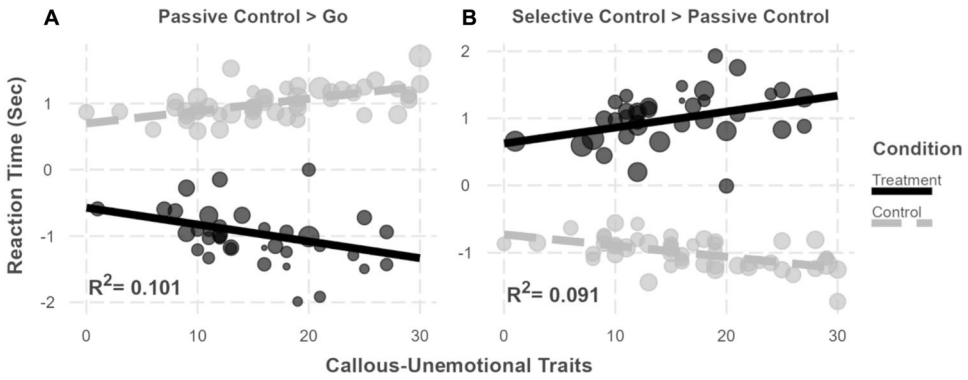

Fig. 2 Depicting the relationship between callous-unemotional traits and reaction time contrasted between trial types by treatment condition. (**A**) Passive Control > Go trials, (**B**) Selective control > Passive control trials

extremely high values suggesting greater load due to unpredictability of response patterns and extremely low values indicating less adaptive and repetitive cognitive strategies due to highly predictable patterns of cognitive function [29, 48, 49]. Interaction terms between group (control or test), CP, and CU traits were derived using residual centering [50, 51] to prevent violating assumptions of residual dependence while retaining unique variance of our interactions to bolster our statistical inferences. All model parameters were bootstrapped with 10,000 resamples to improve (1) tests of interaction effects and (2) adjust p values to correct bias.

Covariates

All analyses controlled for sex at birth, IQ, careless responses, ADHD, and internalizing symptoms. IQ was included to account for its strong relationship to cognitive function [52]. Careless responses were included to account for participant inattentiveness during self-report measures and to bolster estimation of phenotypes on behavioral performance. ADHD and internalizing were included to account for their confounding impact on cognitive performance [53, 54, 56], and relationship with CP and CU traits [57, 58].

As expected, CU, CP, and ADHD were significantly related. Calculating a multiple correlation coefficient determined that 52% of the variance in CU traits and CP was retained. Given this is similar to other studies examining similar aged youth [59, 60] this is adequate variance and placing all variables in our model bolsters statistical inferences by retaining variance unique to each phenotype.

Results

No Sample or Task Performance Abnormalities Detected

Sample phenotype distributions and associations as expected. Distribution for the ICU [61], and SDQ (https://sdqinfo.org/norms/USNorm1.pdf) were within expected distributions for samples in the targeted age range (Table 1). Importantly the distribution of these phenotypes was not significantly different by group assignment (Supplemental Fig. 3). Associations between CU traits, CP, ADHD, and internalizing were positive and CU traits and CP both positively related to delinquency and negatively with prosociality and mentalizing (Supplemental Fig. 4).

SSSST performance as expected between control and test subjects. Test subjects had significantly higher reaction times than those in the control condition (Supplemental Fig. 5). Additionally, the variation on metrics recommended to be reported based on the consensus guidelines by trial type [45] were as expected (i.e., variation and average responses) across the sample as well as by group (Supplemental Table 1).

CU Traits Associated with Better Passive but Worse Selective Control

CU traits: faster reaction times for passive but slower for selective control. CU traits in the test group were distinctly associated with slower reaction times on the overall task ($\beta = 0.160$, $p = 0.005$, $R^2 = 0.221$), go trials ($\beta = 0.453$, $p = 0.002$, $R^2 = 0.290$) and selective control trials ($\beta = 0.397$, $p < 0.001$, $R^2 = 0.309$), but faster reaction times during the passive inhibition trials ($\beta = -0.368$, $p = 0.005$, $R^2 = 0.333$; Table 2, Supplemental Tables 2–5). Reaction time contrasts between trials did not detect a difference between selective control > go trials ($\beta = -0.09$, $p = 0.188$, $R^2 = 0.090$); however, for CU traits in the test group, passive control trials had shorter reaction times than go trials ($\beta = -1.137$, $p < 0.001$, $R^2 = 0.101$) and selective control trials had significantly longer reaction times than passive control trials ($\beta = 1.042$, $p < 0.001$, $R^2 = 0.091$; Table 3, Supplemental Tables 6–9). Neither CP nor the interaction of CP and CU traits in the test group were statistically associated with reaction time.

CU traits: accuracy higher for passive but lower for selective control. CU traits in the test group were distinctly

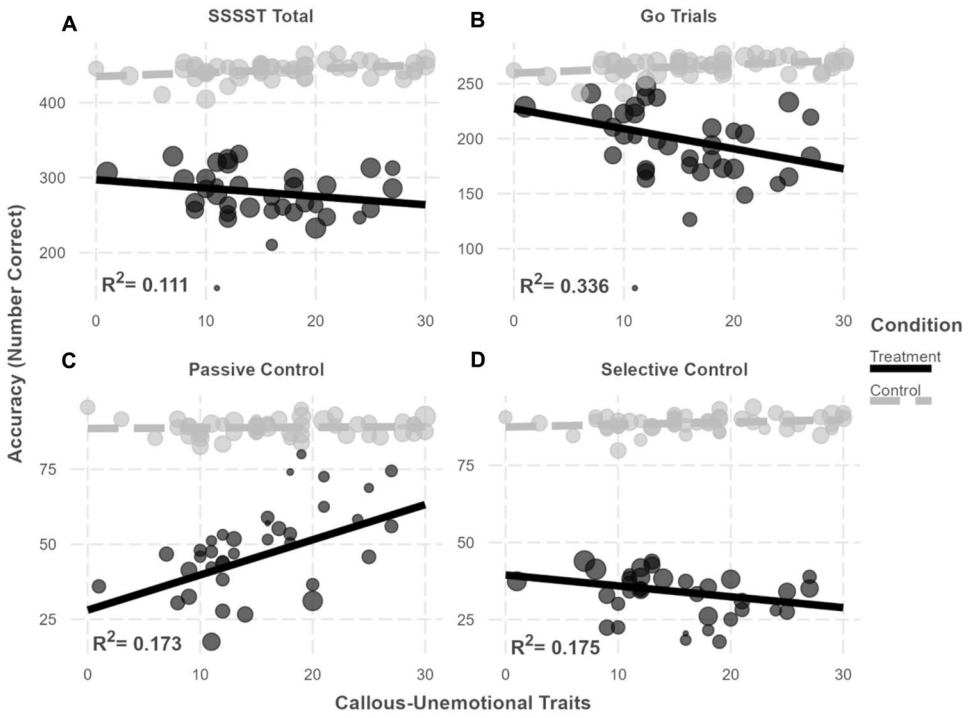

Fig. 3 Depicting the relationship between callous-unemotional traits and accuracy by trial type and treatment condition. (**A**) total Selective Stimulus Stop Signal Task (SSSST), (**B**) Go trials, (**C**) Passive control trials, (**D**) Selective control trials

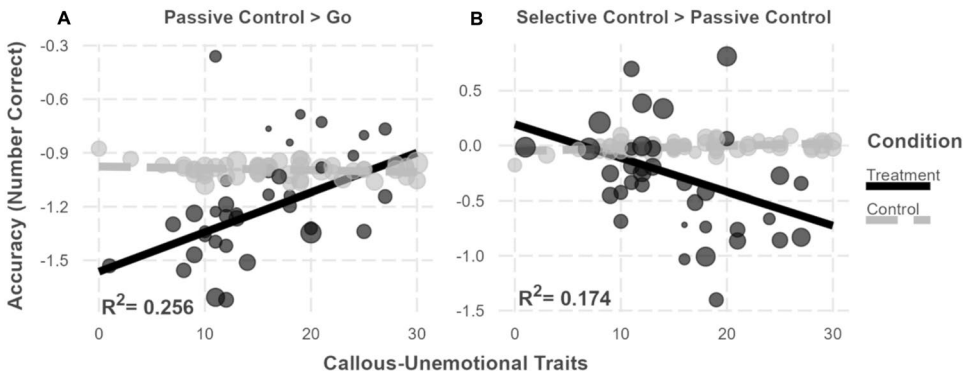

Fig. 4 Depicting the relationship between callous-unemotional traits and accuracy contrasted between trial types by treatment condition. (**A**) Passive control > Go trials, (**B**) Selective control > Passive control trials

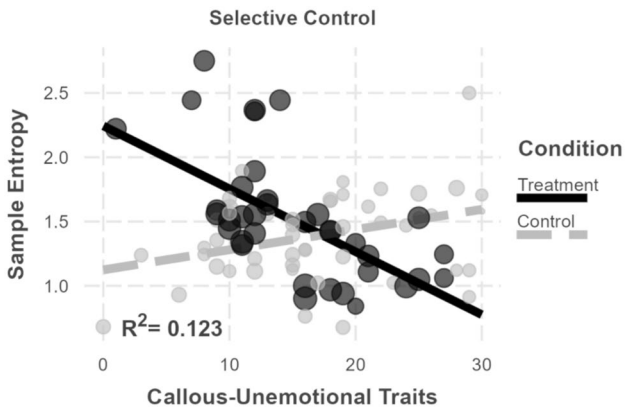

Fig. 5 Depicting the relationship between callous-unemotional traits and entropy for selective control trials by treatment condition

associated with worse accuracy on the overall task (β = – 56.619, p = 0.046, R^2 = 0.111), go trials (β = – 74.076, p = 0.017, R^2 = 0.336), and selective control trials (β = – 11.266, p = 0.004, R^2 = 0.175), but better accuracy during passive inhibition trials (β = 28.723, p = 0.009, R^2 = 0.173; Table 4, Supplemental Tables 9–12). Accuracy contrasts between trials did not detect a difference between selective control > go trials (β = – 0.020, p = 0.778); however, for CU traits in the test group, passive control trials had better accuracy than go trials (β = 0.623, p = 0.007) and selective control trials had significantly worse accuracy than passive control trials (β = – 0.964, p < 0.001; Table 5, Supplemental Tables 13–15). Neither CP nor the interaction of CP and CU traits in the test group were statistically associated with accuracy.

CU trait balanced integration scores were better for passive but worse for selective control. CU traits in the test group were distinctly associated with worse balanced integration scores for the overall task (β = – 2.234, p =

Table 2 Reaction time tests

	β	σ_β	t^+	p^+	Confidence intervals$^+$	
					2.5%	97.5%
Total ~ (R^2 = 0.221)						
CU traits*Test	0.160*	0.057	2.883	0.005	0.129	0.300
CP*Test	−0.003	0.023	−0.107	0.915	−0.052	0.039
CU traits*CP*Test	−0.039	0.025	−1.754	0.083	−0.093	−0.007
Go trials ~ (R^2 = 0.290)						
CU traits*Test	0.453*	0.142	3.190	0.002	0.368	0.814
CP*Test	−0.026	0.057	−0.508	0.613	−0.156	0.073
CU traits*CP*Test	−0.083	0.063	−1.579	0.118	−0.221	−0.003
Passive control trials ~ (R^2 = 0.333)						
CU traits*Test	−0.368	0.138	−2.883	0.005	−0.666	−0.217
CP*Test	0.070	0.056	1.078	0.284	−0.031	0.261
CU traits*CP*Test	0.015	0.061	0.288	0.774	−0.116	0.144
Selective control trials ~ (R^2 = 0.309)						
CU traits*Test	0.397*	0.137	4.580	0.000	0.292	0.708
CP*Test	−0.052	0.056	−1.587	0.116	−0.198	0.041
CU traits*CP*Test	−0.049	0.061	−1.602	0.113	−0.166	0.041

Note: $^+$ = bootstrap corrected with 10,000 resamples.

Table 3 Reaction time contrast tests

	β	σ_β	t^+	p^+	Confidence intervals$^+$	
					2.5%	97.5%
Selective control > Go trials ~ (R^2 = 0.090)						
CU traits*Test	−0.09	0.072	−1.327	0.188	−0.178	0.103
CP*Test	−0.025	0.029	−1.005	0.318	−0.079	0.035
CU traits*CP*Test	0.041	0.032	1.482	0.142	−0.034	0.094
Passive control > Go trials ~ (R^2 = 0.101)						
CU traits*Test	−1.137*	0.385	−5.279	0.000	−1.993	−0.765
CP*Test	0.136	0.156	1.429	0.157	−0.126	0.604
CU traits*CP*Test	0.126	0.170	1.490	0.140	−0.176	0.491
Selective control > Passive control trials ~ (R^2 = 0.091)						
CU traits*Test	1.042*	0.371	4.580	0.000	0.687	1.839
CP*Test	−0.168	0.150	−1.722	0.089	−0.616	0.099
CU traits*CP*Test	−0.079	0.164	−0.972	0.334	−0.417	0.219

Note: $^+$ = bootstrap corrected with 10,000 resamples.

0.013), go trials (β = – 3.040, p = 0.009), and selective control (β = – 1.501, p = 0.007), but better scores for the passive inhibition trials (β = 2.204, p = 0.004; Supplemental Tables 16–19). Neither CP nor the interaction of CP and CU traits in the test group were statistically associated with balanced integration scores.

CU Traits Associated with Worse Cognitive Control

CU trait associated with longer stop signal reaction time. CU traits in the test group were distinctly associated with a longer SSRT (a measure of response inhibition, with longer SSRT indicating less control; β = 0.189, p = 0.026; Supplemental Table 20). Neither CP nor the interaction of CP and CU traits in the test group were statistically associated with SSRT.

CP Associated with Worse Response Inhibition

CP was associated with a shorter maximum stop signal delay. CP in the test group was associated with a shorter maximum stop signal delay (a measure of response inhibition, with longer delays indicating better inhibition; β = −0.059, p = 0.005; Supplemental Table 21). CU traits had no statistically meaningful association with the stop signal delay.

CU Traits Implicated in a Rigid Cognitive Strategy during Selective Control

CU traits associated with lower entropy during selective control. CU traits in the test group were distinctly associated with lower entropy during selective control trials (β

Table 4 Accuracy tests

	β	σ_β	t^+	p^+	Confidence Intervals$^+$	
					2.5%	97.5%
Total ~ (R^2 = 0.111)						
CU traits*Test	−56.619*	32.621	−2.025	0.046	−159.338	−49.368
CP*Test	3.127	13.187	0.197	0.844	−34.301	25.254
CU traits*CP*Test	11.632	14.445	0.839	0.404	−6.318	55.702
Go trials ~ (R^2 = 0.336)						
CU traits*Test	−74.076*	31.145	−2.435	0.017	−174.452	−68.703
CP*Test	4.784	12.590	0.462	0.645	−23.399	22.411
CU traits*CP*Test	13.382	13.791	1.181	0.241	−1.433	50.430
Passive control trials ~ (R^2 = 0.173)						
CU traits*Test	28.723*	10.534	2.674	0.009	15.456	48.512
CP*Test	−2.202	4.258	−0.424	0.673	−17.253	4.634
CU traits*CP*Test	−2.860	4.664	−0.640	0.524	−11.014	10.527
Selective control trials ~ (R^2 = 0.175)						
CU traits*Test	−11.266*	6.643	−2.973	0.004	−24.489	−0.071
CP*Test	0.546	2.686	0.262	0.794	−6.174	7.919
CU traits*CP*Test	1.110	2.942	0.548	0.585	−6.885	8.424

Note: $^+$ = bootstrap corrected with 10,000 resamples.

Table 5 Accuracy contrast tests

					Confidence Intervals$^+$	
	β	σ_β	t^+	p^+	2.5%	97.5%
Selective Control > Go Trials ~ (R^2 = 0.363)						
CU traits*Test	−0.020	0.166	−0.283	0.778	−0.102	0.332
CP*Test	−0.045	0.067	−0.992	0.324	−0.136	0.086
CU traits*CP*Test	0.020	0.074	0.471	0.639	−0.125	0.095
Passive Control > Go Trials ~ (R^2 = 0.256)						
CU traits*Test	0.623*	0.233	2.765	0.007	0.480	1.255
CP*Test	−0.082	0.094	−1.011	0.315	−0.316	0.083
CU traits*CP*Test	−0.053	0.103	−0.689	0.493	−0.274	0.128
Selective Control > Passive Control Trials ~ (R^2 = 0.174)						
CU traits*Test	−0.964*	0.385	−4.144	0.000	−1.701	−0.508
CP*Test	0.092	0.156	1.049	0.297	−0.179	0.573
CU traits*CP*Test	0.094	0.170	1.171	0.245	−0.310	0.374

Note: $^+$ = bootstrap corrected with 10,000 resamples.

= − 1.291, p = 0.011; Supplemental Table 22) but had no statistically meaningful associations for the task overall, go trials, or passive control trials (Supplemental Tables 23–25). Neither CP nor the interaction of CP and CU traits in the test group were statistically associated with entropy.

Discussion

Results from the present randomized controlled trial with a community early adolescent sample demonstrate that decrements in selective control are distinctly linked to CU traits. CU traits were associated with better performance during passive control trials (consistent with other evidence: e.g., [15, 62] and as well as unique decrements in selective control when contrasted with passive control trials. Additionally, CU traits were associated with worse cognitive control and a more rigid cognitive strategy during selective control. In contrast, CP were unrelated to performance on any of the task trials when CU traits were included. These results extend prior work by implicating a specific cognitive function that is unique to CU traits relative to CP by measuring both passive and selective control in one paradigm. Coupled with prior work linking selective control distinctly with CU trait affective deficits [6], this work supports the mounting evidence of a CU traits-specific cognitive-affective difficulty involving a deficit in selective control.

Selective Control Decrements and Rigid Cognition Unique To Callous-Unemotional Traits

CU traits were associated with decrements in selective control for reaction time, accuracy, balanced integration between reaction time and accuracy, contrasts for selective control > passive control, as well as cognitive control metrics. These findings support prior work implicating greater difficulty for adults elevated in CU traits when identifying specific stimuli performance (e.g., [25, 26] and extend it to selective control specifically. Selective control is important for affective processing [5], when identifying another's emotional state [63, 65]. CU traits are distinctly characterized by affective deficits [1] including decrements in processing affect when attributing others' affective state [66]. Affective processing decrements in CU traits (e.g., when attributing affective states) is, at least partially, explained by limitations in selective control [6]. Thus, the present evidence links CU traits with a decrement in a specific cognitive domain, which in turn has been linked with affective processing deficits. These findings converge on selective control as a cognitive function of primary interest for CU traits.

In line with worse performance, CU traits were associated with a more rigid cognitive strategy during selective control trials only. Substantive work in adult literature evidence a more rigid and serial way of cognitively processing information that limits the processing of contextual information that can include others' affect [31, 32], which is relatively untested in adolescents. The present evidence partially supports this view with the inverse relationship to entropy metric along with poor performance. However, this finding was specific to selective control trials and cognitive tasks requiring precursors to selective control have been found more cognitively demanding as a function of CU traits e.g., [24]. Therefore, in adolescents, it may be that a more rigid cognitive strategy is employed when engaging in selective control because it is more demanding for those elevated in CU traits to conserve resources in the short term, but ultimately more demanding in the long term [67]. Such an approach over time would plausibly become more automatic and pronounced even in less demanding processes in adults with psychopathy. Longitudinal examinations with such a paradigm could improve our understanding of this etiology from youth to adults.

Better Passive Control Unique To Callous-Unemotional Traits

CU traits distinctly associated with better performance in passive control for reaction time, accuracy, and balanced integration scores. This is consistent with prior work using traditional stop signal trials (e.g., [14] equivalent to the passive control trials used in the current study. In addition to the finding that CU traits were unrelated to passive trial entropy, results suggest that individuals with CU traits have a normal range of flexibility and difficulty with passive control trials. Thus, if only passive control is tested, one might conclude that CU traits associate with better inhibition, as some work has done (e.g., [15]. However, CU traits were associated with worse performance on the selective control trials, establishing a distinction based on type of inhibitory process. Passive control is less demanding than selective control [13], and the allocation of cognitive control resources depends on the availability of resources and the demands of a given task [18]. This potentially reveals an important context about cognitive demands in the context of antisocial phenotypes. That is, context of the cognitive demands, and the type of cognitive processes, matter for understanding different antisocial phenotypes (e.g.,[68]. Modifications to traditional tasks to incorporate preliminary features of selective control show greater difficulty and worse performance during the traditional task that is specific to CU traits [24]. Thus, it is plausible that selective control is a specific cognitive function that is substantially more demanding for those elevated in CU traits. Conversely, the lower demands of passively not responding to tasks such as the traditional stop signal or go/no-go tasks do not appear to be critical tasks for investigating CU traits.

At the same time, this finding was inconsistent with a meta-analysis on stop signal and go/no-go tasks in adult psychopathy that found worse performance in individuals with CU traits but to a lower degree than those with CP [17]. However, as noted by meta-analyses by Gillespie et al. [17, 69], there are substantial problems with the literature on cognitive function in CP and CU traits that involve substantial variability in how phenotypic groups are created and in the nature of tasks used, which limit reliability of meta-analytic findings. For example, many prior studies have compared groups that are somewhat arbitrarily defined (i.e., based on sample-specific symptom severity vs. established clinical cut-offs) where group definitions were found to influence the results of meta-analytic findings (see [70]. Thus, the discrepancy of present findings with the meta-analysis could be interpreted as highlighting the importance of examining data continuously (as opposed to dichotomizing continuous symptom measures into arbitrary group definitions), as well as further supporting the importance of specificity in the processes being studied for antisocial phenotypes. Therefore, modifying tasks to incorporate selective control processes may help elucidate cognitive contributions to deficits in CU traits.

Response Inhibition Decrements Unique To Conduct Problems

CP were associated with greater difficulty with response inhibition across trials, as evidenced by a significantly shorter stop signal delay. This is consistent with data from Waschbusch [70] that CP is linked with behavioral inhibition difficulties. If impulsive reactions to stimuli result in a lower inhibitory response during the SSSST task, then this would explain why those elevated in CP would have a lower stop signal delay. This was found to be distinct from CU traits well as ADHD symptoms. ADHD shares impulsivity with CP that predicts later criminal activity as an adult [71]. Given that CP were not associated with worse performance on the trials themselves, this may implicate a more general cognitive difficulty with tracking rule changes. Together these finding further evidence that impulsive behavior is a defining feature of CP.

Callous-Unemotional Traits Did not Moderate Conduct Associations with Cognition

Profound and broad cognitive impairments associated with CP have been found to be moderated by CU traits, such that higher CU traits are implicated in either better or mitigated decrements in broad cognitive functions associated with CP (e.g., [15, 62]. However, the present study, which examined more specific cognitive processes unique to CU traits, did not find this interaction. Given that the present study was adequately powered and compared both control and test groups, not finding this interaction suggests there may be cognitive features unique to CU traits on a specific level that are distinct from CP interacting with CU. This also suggests that the interaction between CP and CU traits on cognitive function exists on a broad level of cognitive function, as well as the possibility that there may be specific cognitive functions that are unique to CP and CP interacting with CU traits. Further examination of specific cognitive functions may lead to better understanding of antisocial phenotypes and antisocial etiology.

Limitations

The present study must be interpreted under some limitations. First, the present study was underpowered to examine variants antisocial phenotypes by internalizing symptoms of primary (low internalizing) and secondary (high internalizing). Although we controlled for internalizing symptoms that partially accounts for this, larger samples are need to determine if there are features distinct to one or both variants. Second, puberty was not included as a covariate due to a technical error during collection. Advanced pubertal development at an earlier age is a feature predicting CU trait severity e.g., [72]. Controlling for internalizing may have mitigated this because of its close link with pubertal onset [73, 74] given that age and puberty are not as closely related and controlling for age is less suitable for the study of a limited age range <5 years [75]. Third, measurements from a single cognitive task are subject to errors (e.g., [7]; however, the present task had a substantial number of trials (450 trials) to improve reliability of this measurement, and this single task afforded more incisive examinations of cognitive processes. Fourth, the ICU measure has, in some samples, shown variability related to sample characteristics [76], which may indicate potential limitations in smaller samples. However, the ICU has been shown to be the most relevant for predicting antisocial outcomes [77] indicating it was appropriate for the current study. Using alternative multidimensional measures in future work would be important for determining if the same conclusions are reached [78]. Finally, while the community adolescent sample provides advantages for understanding CU traits and CP by representing similar deficits as incarcerated samples and having the variance to detect detailed effects, these results may not completely reflect the profound impairments of clinical or incarcerated samples.

Conclusion

The present findings from a randomized controlled parallel-arm design provide evidence that CU traits are associated with difficulties during selective control (i.e., the capacity to selectively inhibit a prepotent response to a specific stimulus for an alternative response). Selective control is a specific cognitive function that is implicated in a variety of day-to-day functions, including the capacity to process affect to learn from and understand others' affective states [5,63, 65, 79, 80]. Affective deficits in guilt, remorse, and empathy define CU traits [1] and affective processing to understand others' affective states has initial evidence implicating difficulties in selective control [6]. Selective control difficulties studied here advance this work by demonstrating it is not due to a general difficulty with higher cognitive demands, but rather specific to the cognitive demands and function of selective control. CU traits, consistent with prior literature, were associated with better passive control when participants did not respond to certain trials. Given these passive control tasks and non-response trials have been found considerably less demanding [13], these contrasting results highlight the importance of cognitive demands in conjunction with the specific processes tested for examining CU traits. Interestingly, CU traits are associated with cognitive rigidity during selective control trials. This suggests

there may be a unique induction of less adaptive cognitive strategies to tasks with higher cognitive demands that may be specific to selective control. Unlike investigations of more general cognitive tasks, the present study did not find CU traits as a moderator for CP associations with specific cognitive functions. This further supports the idea that a difficulty in selective control is unique to CU traits. By linking CU traits to decrements in selective control, the present findings substantiate the consideration of specific cognitive functions to understand antisocial etiology in future work.

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Data Availability Once all preregistered analyses are complete data will be deposited to the following DOI: DOI 10.17605/OSF.IO/YHQJP.

Declarations

Competing Interests The authors declare no competing interests.

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