Reciprocal effects between negative parenting and children's callous-unemotional traits from mid to late childhood

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Abstract

Objective. The role of negative parenting in the development of callous-unemotional (CU) traits remains unclear. Both negative parenting and CU traits are influenced by genetic and environmental factors. To date, genetically informed longitudinal cross-lagged models have not been used to examine to what extent reciprocal effects between negative parenting and children's CU traits in mid-to-late childhood are genetic vs. environmental in origin.

Methods. In 9,260 twin pairs from the Twins Early Development Study, we estimated cross-lagged effects between negative parenting (discipline and feelings) and children's CU traits from mid (7–9y) to late (9–12y) childhood.

Results. CU traits were strongly heritable and stable. Stability was largely explained by genetic factors. The influence of negative parenting on the development of CU traits was small and mostly driven by genetic and shared environmental factors. In mid-childhood, the influence of children's CU traits on subsequent negative parenting (i.e., evoked by children's CU traits) was also small and mostly genetic in origin. In late childhood, CU traits showed no effects on negative parental discipline and small effects on negative parental feelings, mostly reflecting shared environmental factors.

Conclusions. In mid-to-late childhood, genetic factors strongly influence the development of CU traits, whereas environmental effects of negative parenting are small. Negative parenting is also relatively unaffected by CU traits. The small reciprocal effects mostly originate from genetic and shared environmental factors. Therefore, repeated intensive interventions addressing multiple risk factors vs. negative parenting alone may be best positioned to support families of children with CU traits across development.

Introduction

The association between negative parenting and callous-unemotional traits

Parental discipline and feelings are considered to play a central role in children's psychosocial development. Negative parental discipline (e.g., smacking and shouting) and feelings (e.g., emotional inconsistency) have been linked with poor child outcomes (1–3). However, some of the association between parenting by biological parents and children's outcomes can be explained by the genetic variants they share. Therefore, designs that account for possible genetic confounding of familial associations are best suited to explore parent-child relationships (4). Genetically informed studies have indicated that the association between parenting and child outcomes often reflects, at least partly, gene-environment correlation (*r*GE), particularly passive and evocative *r*GE. Passive *r*GE refers to instances when the child's behavior and the environment provided by their parent correlate, as they both partly originate in the parent's genotype. For example, genetic variants that influence parental negativity may also influence child difficult temperament. Thus, associations between parental negativity and child temperament will be partly due to genetics. Evocative *r*GE refers to instances where child's heritable characteristics influence parental responses. Children with easier temperament elicit warmer parenting, whereas children who display disruptive behavior are met with harsher parenting (5,6). Nonetheless, child effects on parenting have received less empirical attention than parenting effects on child outcomes (7,8).

The relationship between negative parenting and callous-unemotional (CU) traits is of interest, since CU traits are a developmental risk factor for persistent conduct problems in childhood (9,10) and antisocial behavior and psychopathy in adulthood (10). CU traits include shallow affect, lack of empathy, guilt, and remorse (11), and are moderately to highly heritable

(36—78%) (12–15). Understanding how parenting impacts the development of CU traits is necessary because parenting programs are the most common interventions for children with conduct problems and elevated CU (16). Since children with elevated CU traits can evoke negative parental responses (17,18), it is important to also consider possible child effects.

Extent and nature of the longitudinal association between negative parenting and CU traits

Parental discipline and feelings have been related to CU traits cross-sectionally and longitudinally in observational studies (19–22). For example, harsh parenting at children's age 2 has been associated with a small increase in children's CU behavior at age 3 (20). Conversely, warm parenting at age 2 has been associated with a small decrease in CU behavior at age 3 (23). Findings concerning child effects are inconsistent. For example, CU behavior at age 2 has been associated with a small decrease in parental warmth at age 3 (23), whereas CU traits at age 3 has been associated with a small increase in positive parenting practices at age 6 (24). In children aged 3–10, CU traits have been associated with a small increase in inconsistent parental discipline and punishment, and a small decrease in parental involvement one year later (17). Studies examining longitudinal reciprocal effects are required to clarify whether CU traits are longitudinally associated with an increase or decrease in negative parenting.

One possible explanation for the modest associations estimated in previous studies spanning months or years is that robust reciprocal influences may be most evident within shorter time intervals. For example, parents might experience strong negative feelings during the hours/days following a child's provocation, and vice versa (25). Nonetheless, studies conducted over years can complement studies with closer observation intervals by detecting cumulative effects that may gradually consolidate and become apparent over time. These studies can provide particularly valuable insight when utilizing designs that enable the estimation of the etiological factors shaping long-term parent-child dynamics across developmental stages.

Fewer studies have been conducted on this topic using genetically informed designs, such as adoption and twin designs (26,27). Adoption and twin studies have indicated that, in early childhood, both genetic risk and environmental effects of parenting influence the development of CU traits (28,29). For example, positive reinforcement by adoptive mothers at 18 months has been found to attenuate the association between genetic risk for CU behaviors (indexed by antisocial behavior in biological mothers) and CU behaviors at 27 months, suggesting that positive parental discipline can protect against genetic risk for CU traits (30,31). In twins aged 6-11, parental involvement has been found to reduce genetic risk for CU traits, whereas parental conflict has been found to increase it (32). However, there is also evidence challenging the prevailing view of parenting as an environmental influence on the development of CU traits. For example, a monozygotic twin differences study found no association between negative parental discipline at age 7 and CU traits at age 12 when controlling for earlier child behavior problems (33). No association has also been observed between retrospectively-reported negative parenting and adult callous affect (34). Therefore, study designs that can discern the genetic vs. environmental nature of parent- and child-driven effects are needed to determine the role of parenting in the development of CU traits more conclusively. This is especially crucial for negative dimensions of parenting, which have shown higher heritability and stronger genetic associations with CU traits compared to positive dimensions, suggesting that negative parenting might be especially influenced by heritable child characteristics (32,35).

Genetically informed cross-lagged models provide a means to investigate the nature of longitudinal reciprocal effects between two variables. To date, only two studies have used such models to examine negative parenting and CU traits, both of which focused exclusively on early childhood (36,37). In 561 adoptive families, Trentacosta and colleagues found that harsh parenting by adoptive mothers at 27 months predicted small increases in CU traits at 54 months (and vice versa), while no reciprocal effects emerged between 18 and 27 months (37). In 169 twin pairs, Flom and colleagues found no effects of negative parental feelings at age 2 on CU traits at age 3. Child effects were statistically significant and driven by genetic and nonshared environmental factors but contributed less than 1% of the variance in negative parenting. Applying genetically informed cross-lagged models in mid-to-late childhood is required to elucidate the nature of parent-child effects across development.

The current study

We investigated the longitudinal co-development of negative parenting (discipline and feelings) and children's CU traits from mid (7–9y) to late (9–12y) childhood. We examined genetic and environmental influences on the variance and stability in negative parenting and CU traits. Consistent with prior research (38), we predicted moderate to strong genetic influences on the variance and stability in CU traits. Using cross-lagged twin models, we estimated the extent and nature of the cross-sectional associations and cross-lagged effects between negative parenting and children's CU traits to address the following pre-registered research questions: 1) To what extent are longitudinal reciprocal effects genetic and environmental in origin? 2) Do such effects vary from mid to late childhood? We predicted statistically significant longitudinal reciprocal effects, and that the extent and etiology of these effects would vary over time.

Methods

The pre-registered project and scripts are available on OSF (osf.io/bc9n7; osf.io/85z2w).

Participants

We used data from the Twin Early Development Study (TEDS), a longitudinal study of twins born in England and Wales between 1994–1996. Data collection was approved by the ethics committee for the Institute of Psychiatry, Psychology, and Neuroscience at King's College London. Parents provided informed consent to participate in each assessment. Zygosity was determined using a parent-rated questionnaire on physical similarity showing 95% accuracy relative to DNA marker testing (39), or DNA marker testing when zygosity was unclear. More details on recruitment procedure and representativeness of UK households are reported elsewhere (40,41). After excluding twins with serious medical conditions, our sample comprised 6,491 MZ twins (3,054 males, 3,437 females) and 12,029 DZ twins, including 6,015 same-sex pairs (2,950 males, 3,065 females) and 6,014 opposite-sex pairs (3,010 males, 3,004 females). Most (93%) were White.

Measures

The measures used in the present study are reported verbatim in Supplementary table S1. We measured negative parental discipline with four items from the parenting domain of a semi-structured interview (42). Specifically, parents reported how often they used various strategies to deal with child misbehavior, such as smacking and shouting. We measured negative parental feelings with seven items from the Parental Feelings Questionnaire (PFQ) (43). Parents reported how often they experienced various feelings towards their twins (e.g., feeling frustrated by them). We measured CU traits using four items from the Strengths and Difficulties Questionnaire (SDQ) (44) and three items from the CU subscale of the Antisocial Process Screening Device (APSD) (45,46). Parents answered questions for each twin separately. Nearly all questionnaires were completed by biological mothers at age 7 and 9 (98%; information not collected at 12y).

Although measures of CU traits were also obtained from teachers, we focused on parent reports as they reflect parents' perception of child behavior, which can be expected to drive parental responses. In large-scale longitudinal studies like TEDS, measures are selected to optimize informativeness and conciseness, and to avoid overburdening participants. Accordingly, the TEDS team selected items capturing hallmark features of negative parenting and CU traits, guided by prior studies and statistical checks on pilot data. Several studies have validated the use of combinations of SDQ and APSD items to measure CU traits in TEDS (12,38) and external datasets (47,48). Similarly, previous studies have supported the validity of our measures of negative parental discipline and feelings in TEDS (49,50) and external datasets (51–53). Our measures of CU traits (51) and negative parenting (53) have also shown convergent validity with other measures of the same constructs, and criterion validity with related constructs like conduct problems and difficult temperament (9,52) as well as parenting practices and adjustment (54).

Composite scores of CU traits were computed as mean scores; composite scores of negative parental discipline and feelings were available in TEDS as mean scores (age 7 and 12) and sum scores (age 9). Items were reverse-coded as needed, except for the negative parental feelings scale at age 7, computed by the TEDS team subtracting positive items from negative items. Composite scores showed acceptable validity, with omega values around or above .60 (55,56), good reliability, with Intraclass Correlation Coefficients above .60 (57), and acceptable model fit for the one-factor models (58). Scores were standardized before analysis. More details in Supplementary Table S2.

Statistical Analyses

We inspected the distribution of negative parenting and children's CU traits and then estimated their etiology using univariate twin models (59). Univariate twin models leverage differences in genetic relatedness between monozygotic (MZ) and dizygotic (DZ) twins to estimate additive genetic influences (denoted as “A”), shared environmental influences, promoting twin similarity (“C”, e.g., aspects of the family environment affecting them equally), and nonshared environmental influences, contributing to their differences (“E”, including measurement error) (59). Next, we examined cross-sectional and longitudinal relationships between negative parenting and CU traits, and the etiology of these relationships, using cross-lagged twin models (60), illustrated in Supplementary Figures S1–S4. Cross-lagged twin models (4) decompose trait variance into pre-existing and novel etiological influences. Furthermore, they estimate etiological influences on cross-sectional associations and cross-lagged effects (i.e., partial regression coefficients controlling for correlations at previous time points) (60–63).

We estimated two cross-lagged twin models, one for negative parental discipline (Model 1), one for negative parental feelings (Model 2). We additionally specified the same models using teacher reports of CU traits (Supplementary Table S6). Models were built in three steps. First, we estimated the phenotypic structure. Second, we partitioned the variance in the phenotypic paths into A, C, and E. Third, we specified model constraints. This included constraining nonsignificant paths to zero, including the C component for CU traits at age 7 (Models 1 and 2) and the cross-lagged path from CU traits at age 9 to negative parental discipline at age 12 (Model 1). We also specified equality constraints on the cross-lagged paths between mid and late childhood. Specifically, we constrained the cross-lagged path from negative parental discipline to CU traits at 7-9y and at 9-12y to be equivalent, and examined whether this constraint significantly decreased model fit using the Likelihood Ratio Test. The same process was repeated for negative parental feelings and for the cross-lagged paths from CU traits to negative parenting. Analyses were conducted in R (64), packages psych (65), lavaan

(66), OpenMx (67), and TwinAnalysis (68). As per recent guidelines (69), we considered estimates ≦.10 as very small, .11–.20 as small, .21–.30 as moderate, .31–.40 as large, ≧.40 as very large.

Results

Univariate Results

Descriptive statistics are in Supplementary table S2, univariate ACE results in Figure 1. Variance in CU traits was largely explained by additive genetic factors (67%, 51%, 55%). Variance in negative parental discipline was explained largely by additive genetic factors at age 7 (58%) and by shared environmental factors at age 9 and 12 (80, 84%). Variance in negative parental feelings was mostly explained by additive genetic factors across time points (40%, 59%, 45%), despite again increasing shared environmental influences (29%, 31%, 43%).

[INSERT FIGURE 1 HERE]

Multivariate Results

Cross-lagged twin models showed excellent fit (*Model 1*: RMSEA = .02; CFI = .99; *Model 2*: RMSEA = .03; CFI = .99) and are illustrated in Figures 2–3 (CIs in Tables 1–2; phenotypic correlations in Supplementary Table S4; phenotypic cross-lagged models by sex in Supplementary Table S5). Models using teacher reports provided broadly consistent results, albeit with smaller phenotypic estimates due to informant discrepancy (Supplementary Table S6).

[INSERT FIGURES 2–3 HERE]

[INSERT TABLES 1–2 HERE]

Model 1 – Negative parental discipline and children's CU traits

Stability. CU traits showed very strong longitudinal stability in mid-childhood (7–9y, β = .46) and late childhood (9–12y, β =.50), largely explained by additive genetic factors (84%, 83%). Negative parental discipline was moderately stable in mid-childhood (β = .29) and very stable in late childhood (β = .46). Additive genetic and shared environmental factors each explained about half of the stability in mid-childhood; shared environmental factors mostly explained stability in late childhood (82%).

Cross-sectional associations. At age 7, additive genetic and nonshared environmental factors each explained about half of the small cross-sectional association (r = .20). At age 9, the small cross-sectional association (r = .13) was fully explained by shared environmental factors. At age 12, the very small cross-sectional association (r = .08) was largely explained by shared environmental factors (88%).

Cross-lagged effects. In mid-childhood, the small cross-lagged parenting effect (β = .10) was largely explained by additive genetic factors (80%). The very small cross-lagged child effect (β = .05) was fully explained by additive genetic factors. In late childhood, the small cross-lagged parenting effect (β = .10) was entirely explained by shared environmental factors. Child effects were non-significant. Constraining phenotypic cross-lagged paths from negative parenting to CU traits to be equal in mid and late childhood did not reduce model fit significantly (ΔLL = .04, Δdf = 1.00, p = 0.841).

Model 2 – Negative parental feelings and children's CU traits

Stability. CU traits were highly stable in mid-childhood (7–9y, β = .51) and late childhood (9–12y, β =.50). Stability was largely explained by additive genetic factors (86%, 68%). Negative parental feelings showed very strong stability in mid-childhood (β = .47) and late childhood (β = .58), largely explained by additive genetic factors (80%, 70%).

Cross-sectional associations. At age 7, the moderate cross-sectional association (*r* = .24) was mostly due to additive genetic factors (69%). At age 9, the small cross-sectional association (*r* = .17) was mostly due to shared environmental factors (49%). At age 12, the small cross-sectional association (*r* = .13) was mostly due to shared environmental factors (54%).

Cross-lagged effects. In mid-childhood, the small cross-lagged parenting effect (β = .10) was mostly due to shared environmental factors (57%). The small cross-lagged child effect (β = .08) was largely explained by additive genetic factors (77%). In late childhood, the small cross-lagged parenting effect (β = .11) was largely due to additive genetic factors (77%). The very small cross-lagged child effect (β = .07) was largely due to shared environmental influences (60%). Constraining the phenotypic cross-lagged paths in mid and late childhood equal did not significantly decrease fit (parenting effect: ΔLL = .03, Δdf = 1.00, *p* = 0.866; child effect: ΔLL = .02, Δdf = 1.00, *p* = 0.881).

Discussion

The current study examined the nature of longitudinal reciprocal effects between negative parenting (discipline and feelings) and children's CU traits from mid to late childhood using cross-lagged twin models. Variance and stability in CU traits were largely driven by genetic factors. As predicted, longitudinal reciprocal effects were statistically significant, albeit small, except for child effects on negative parental discipline in late childhood. Genetic and shared environmental factors mostly accounted for longitudinal reciprocal effects. Contrary to predictions, the cross-lagged effects did not vary in magnitude over time. However, as predicted, their etiology (i.e., relative contribution of genetic and environmental factors) did.

Genetically informed designs are best suited to investigate putative environmental influences of negative parenting on the development of CU traits

The finding that variance and stability in CU traits are mainly driven by genetic factors aligns with prior research (38). Genetic stability does not imply that CU traits are unchangeable (70). As for other highly heritable traits (e.g., weight), environmental influences (e.g., exercise) can buffer against genetic risk (29,71). Indeed, positive parenting can reduce disruptive behavior in children with high CU traits (72,73), protecting against genetic risk (30–32). Therefore, genetic stability should not be misconstrued as a barrier to effective environmental interventions. Rather, it suggests that “single-shot” interventions may not produce lasting changes in CU traits, consistent with prior evidence of short-term environmental effects on the development of CU traits (12,38,74) and conduct problems (70). Given the importance of genetic factors in shaping the development of CU traits, genetically-informed research on CU traits and related conditions (e.g., disruptive behavior disorders) can offer valuable insights for early detection and treatment delivery (75). However, these conditions have received limited attention in psychiatric genetic research (76), potentially due to concerns regarding misinterpretation and misuse of the findings (77). Patient and public involvement in genetically informed research could be one fruitful avenue to advance this line of research and ensure responsible knowledge dissemination.

Variance and stability in negative parental discipline was primarily influenced by genetic factors in mid-childhood, while shared environmental factors predominated in late childhood. A similar pattern was observed for negative parental feelings, except stability was driven primarily by genetic factors at both stages. Increasing shared environmental influences on negative parenting means that parents rated their own parenting as distinct for each of their twins in mid-childhood, but less so in late childhood. High heritability estimates in mid-childhood can be attributed to more similar ratings for MZ vs. DZ twins, while high shared environmental estimates in late childhood can be attributed to similar parenting regardless of twin zygosity.

This suggests that parental discipline may become less tailored to children's characteristics as they grow older. Supporting parents in modulating their responses to each child could thus be a potential intervention target.

Small longitudinal reciprocal effects between negative parenting and CU traits from mid to late childhood

Negative parenting has been associated with children's CU traits cross-sectionally and longitudinally, although associations have typically been small-to-moderate (19). Here, we found small cross-sectional associations and longitudinal reciprocal effects. These findings do not mean that developmental outcomes are impervious to the influence of parenting; however, they indicate that the effects of parenting on the development of CU traits are limited in mid-to-late childhood, at least outside intervention settings.

It might be reasonable to assume that negative parenting would have larger effects on CU traits at earlier stages, when most aspects of a child's life are under parental control. However, previous cross-lagged twin studies in toddlers have not supported this possibility (36,37). Parenting effects may be small in the context of conventional parenting practices, but larger in the case of highly maladaptive parenting or controlled intensive parenting interventions ("therapeutic parenting"). This possibility aligns with evidence of moderate longitudinal associations between parent-perpetrated childhood maltreatment and CU traits in adolescence and adulthood (78–80). It also aligns with the promising results of intensive parenting interventions providing substantial scaffolding for parents (81), although adequately powered studies with long-term follow-ups are lacking (82).

The impact of CU traits on negative parenting was also small, consistent with a prior cross-lagged twin study spanning a shorter period (1y) (36). As with parenting effects, child effects may be more detectable when they vary substantially from the norm. For example, children may have a greater influence on parenting when they possess particularly challenging characteristics, such as difficult temperament (8) and high CU traits coupled with antisocial behavior (83).

Since immediate reciprocal influences between CU traits and parenting can shape parent-child dynamics, it is possible that more proximal measurement occasions would reveal stronger effects. The extent of immediate relative to cumulative effects is unclear, as most longitudinal studies, including ours, involved measurements across months/years. One potential way forward is to combine knowledge on proximal and cumulative effects by incorporating momentary assessments in longitudinal data collections (84). This approach would provide a richer understanding of how parent-child dynamics evolve within and between developmental stages. For example, large immediate but marginal cumulative effects would emphasize the importance of evaluating long-term effectiveness of parenting interventions.

Studying positive rather than negative dimensions of parenting might yield different results. Positive parenting (e.g., parental warmth) has been found to protect against genetic risk for CU traits (30,31) and exhibit lower heritability and genetic correlations with CU traits (32,35). Therefore, positive parenting may be less influenced by heritable child characteristics. Future research using positive parenting measures would enable examining this possibility. Future studies may also consider conducting more comprehensive assessments of the target constructs and including information from multiple raters. This could provide further nuance for understanding the impact of specific aspects of parenting across development.

We should also note that our sample was predominantly White, and reciprocal effects may differ in cultures with different parenting practices. Extant studies of CU traits in non-Western participants have found no cultural differences in the etiology of CU traits (85,86), but cultural differences in the etiology of the association between negative parenting and CU traits remain to be examined.

Genetic and shared environmental factors mostly underlie longitudinal reciprocal effects

The small longitudinal reciprocal effects between negative parenting and children's CU traits were driven by both genetic and environmental factors, and the relative importance of the two varied over time. In mid-childhood, cross-lagged effects between negative parental discipline and CU traits were mainly driven by genetic factors. In late childhood, parenting effects were entirely due to shared environmental factors, and no child effects emerged. Concerning negative parental feelings, cross-lagged effects on CU traits were mainly due to shared environmental factors in mid-childhood, then mainly to genetic factors. The opposite was found for child effects (i.e., mainly due to genetic factors in mid-childhood, then by shared environmental factors).

Genetic influences on longitudinal reciprocal effects between negative parenting and children's CU traits mean that individual differences in negative parenting that are genetic in origin impact subsequent CU traits, and vice versa. Notably, since we measured negative parenting as reported by parents, genetic influences on parenting do not reflect the genetics of parents – as would be the case in children-of-twins design – but rather the genetics of children. Because cross-lagged estimates from age 9 to 12 essentially control for the impact of earlier CU traits on subsequent paths from negative parenting to CU traits, we can hypothesize that genetic influences on parenting effects were driven by heritable child characteristics other than CU traits, unmeasured in the current study. Moreover, genetically driven child effects on later negative parenting provide support for evocative *r*GE, meaning that parenting is partly evoked by heritable characteristics in the child, including genetic risk for CU traits (87).

Shared environmental influences on longitudinal reciprocal effects between negative parenting and children's CU traits mean that environmental factors that increase twin similarity also contribute to maintaining the coupling of negative parenting and CU traits over time. Shared environmental influences may reflect several processes that are poorly optimized in families of children with CU traits, such as high conflict and low social support (28,88,89).

Implications for interventions supporting families of children with CU traits

Our findings have several potential implications for interventions. First, small parenting effects on the development of CU traits imply that supported, therapeutic parenting may be required to influence the development of CU traits. Randomized controlled trials have shown encouraging short-term therapeutic parenting effects on disruptive behaviors and CU traits (81). More clinical research is needed to determine the adequate intensity and duration of support for parents of children with varying levels of CU traits. Furthermore, a single-shot intervention may not be sufficient, and interventions with 'booster' protocols may be beneficial. Second, small parenting effects indicate that interventions addressing multiple environmental risk factors vs. parenting alone are better suited to influence the development of CU traits (10). Just as we would not expect single genes to explain substantial variance in complex traits, we may need to move towards examining multiple environmental risk factors simultaneously (90). For example, another risk factor for CU traits is violence exposure at school and in the community (91–93). Multivariate studies can help identify additional risk factors and estimate the relative proportion of variance they explain in CU traits (94). Third, child effects on parenting, albeit small, should also be considered when designing interventions. In addition to training parenting strategies, which children with CU traits are sometimes unresponsive to (95), interventions could foster parental resilience to challenging behaviors, for instance by offering support to handle stress and fatigue associated with parenting (25). This could promote longer intervention adherence, with potential positive ripple effects on children. Lastly, our study replicated prior evidence that the etiology of CU traits changes across development (12,74,89), which attests to their malleability. We further identified changes in the etiology of child effects on negative parenting. Rather than discouraging parenting interventions, these findings suggest that combining parent support with child-focused strategies targeting behaviors that may elicit negative responses represents a promising approach.

Conclusions

In summary, we found small longitudinal reciprocal effects between negative parenting and children's CU traits in mid-to-late childhood, largely driven by genetic and shared environmental factors. This suggests that repeated intensive parenting interventions supplemented by targeting other relevant risk factors, parent support, and child-focused work, may be required to influence the development of CU traits in mid-to-late childhood. This study has several strengths, including its focus on reciprocal transactions between children and their biological parents, the longitudinal design, large sample size, and genetically-informed approach including cross-lagged twin models. Similar to other large-scale studies, however, our measurements relied on selected items (vs. comprehensive assessments) administered at relatively wide time intervals. Future studies could expand upon our findings by examining the etiology of short-term transactions and considering multiple dimensions of parenting.

Authorship

Conceptualization (EV, PP, JBP, MM, IV); Data curation (PP); Methodology (PP, IV, MM, EV, JBP); Supervision (EV, JBP); Formal Analysis (PP, IV); Visualization (PP, IV); Writing, original draft (PP, EV, JBP, IV, EM, MM, PF); Writing, review & editing (PP, EV, JBP, IV, MM, PF, EM).

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Tables

Table 1. *Cross-lagged twin Model 1, parameter estimates*

			β	lCI	uCI	A (%)	lCI	uCI	C (%)	lCI	uCI	E (%)	lCI	uCI
Trait variance														
CU traits, age 7			1.00	1.00	1.00	0.67	0.66	0.68	0.00	0.00	0.00	0.33	0.32	0.34
CU traits, age 9			0.72	0.70	0.74	0.30	0.25	0.35	0.44	0.40	0.48	0.26	0.24	0.28
CU traits, age 12			0.62	0.59	0.64	0.41	0.35	0.46	0.25	0.20	0.30	0.34	0.32	0.37
Negative parental discipline, age 7			1.00	0.00	0.00	0.54	0.51	0.58	0.18	0.15	0.21	0.28	0.27	0.29
Negative parental discipline, age 9			0.85	0.82	0.88	0.14	0.13	0.16	0.83	0.81	0.84	0.03	0.03	0.03
Negative parental discipline, age 12			0.79	0.78	0.81	0.12	0.11	0.13	0.83	0.82	0.84	0.04	0.04	0.05
Trait stability														
CU traits, age 7	-->	CU traits, age 9	0.46	0.44	0.48	0.84	0.82	0.86	0.00	0.00	0.00	0.16	0.14	0.18
CU traits, age 9	-->	CU traits, age 12	0.50	0.48	0.53	0.83	0.77	0.85	0.00	0.00	0.06	0.17	0.14	0.19
Negative parental discipline, age 7	-->	Negative parental discipline, age 9	0.29	0.28	0.31	0.54	0.48	0.61	0.44	0.37	0.49	0.02	0.01	0.04
Negative parental discipline, age 9	-->	Negative parental discipline, age 12	0.46	0.43	0.48	0.18	0.16	0.19	0.82	0.80	0.83	0.01	0.00	0.01
Cross-sectional associations														
CU traits, age 7	<->	Negative parental discipline, age 7	0.20	0.19	0.21	0.55	0.50	0.60	0.00	0.00	0.00	0.45	0.40	0.50
CU traits, age 9	<->	Negative parental discipline, age 9	0.13	0.11	0.15	0.07	0.00	0.17	0.92	0.82	1.00	0.01	0.00	0.03
CU traits, age 12	<->	Negative parental discipline, age 12	0.08	0.07	0.09	0.00	0.00	0.14	0.88	0.75	0.91	0.12	0.09	0.16
Cross-lagged effects														
CU traits, age 7	-->	Negative parental discipline, age 9	0.05	0.04	0.07	0.94	0.85	1.00	0.00	0.00	0.00	0.06	0.00	0.15
CU traits, age 9	-->	Negative parental discipline, age 12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Negative parental discipline, age 7	-->	CU traits, age 9	0.10	0.08	0.12	0.80	0.69	0.93	0.09	0.00	0.21	0.11	0.04	0.21
Negative parental discipline, age 9	-->	CU traits, age 12	0.10	0.07	0.12	0.04	0.00	0.17	0.94	0.80	1.00	0.02	0.00	0.04

Note. CU traits = Callous-unemotional traits; β = Standardized regression coefficient; A = Additive genetic influences; C = Shared environmental influences; E = Nonshared environmental influences; lCI = bootstrap 95% confidence intervals, lower bound; uCI = bootstrap 95% confidence intervals, upper bound;--> = One-way path (stability and cross-lagged paths); <-> = Two-way path (variance and cross-sectional covariance).

Table 2. *Cross-lagged twin Model 2, parameter estimates*

			β	lCI	uCI	A (%)	lCI	uCI	C (%)	lCI	uCI	E (%)	lCI	uCI
Trait variance														
CU traits, age 7			1.00	1.00	1.00	0.67	0.65	0.68	0.00	0.00	0.00	0.33	0.32	0.35
CU traits, age 9			0.62	0.57	0.67	0.39	0.33	0.45	0.33	0.26	0.39	0.28	0.26	0.31
CU traits, age 12			0.63	0.61	0.65	0.41	0.35	0.46	0.26	0.21	0.31	0.33	0.31	0.35
Negative parental feelings, age 7			1.00	0.00	0.00	0.46	0.42	0.49	0.24	0.21	0.26	0.31	0.30	0.32
Negative parental feelings, age 9			0.61	0.57	0.64	0.23	0.18	0.28	0.59	0.54	0.63	0.18	0.17	0.20
Negative parental feelings, age 12			0.58	0.56	0.60	0.39	0.35	0.43	0.42	0.38	0.45	0.19	0.18	0.21
Trait stability														
CU traits, age 7	-->	CU traits, age 9	0.51	0.49	0.53	0.86	0.84	0.88	0.00	0.00	0.00	0.14	0.12	0.16
CU traits, age 9	-->	CU traits, age 12	0.50	0.48	0.53	0.68	0.63	0.73	0.14	0.09	0.18	0.18	0.16	0.20
Negative parental feelings, age 7	-->	Negative parental feelings, age 9	0.47	0.45	0.49	0.80	0.73	0.88	0.10	0.03	0.16	0.10	0.08	0.12
Negative parental feelings, age 9	-->	Negative parental feelings, age 12	0.58	0.55	0.61	0.70	0.65	0.76	0.25	0.19	0.30	0.05	0.04	0.06
Cross-sectional associations														
CU traits, age 7	<->	Negative parental feelings, age 7	0.24	0.23	0.25	0.69	0.65	0.72	0.00	0.00	0.00	0.31	0.28	0.35
CU traits, age 9	<->	Negative parental feelings, age 9	0.17	0.14	0.20	0.35	0.20	0.49	0.49	0.36	0.62	0.16	0.12	0.21
CU traits, age 12	<->	Negative parental feelings, age 12	0.13	0.11	0.14	0.19	0.02	0.35	0.54	0.40	0.68	0.26	0.22	0.32
Cross-lagged effects														
CU traits, age 7	-->	Negative parental feelings, age 9	0.08	0.05	0.10	0.77	0.75	0.82	0.00	0.00	0.00	0.23	0.18	0.27
CU traits, age 9	-->	Negative parental feelings, age 12	0.07	0.05	0.10	0.28	0.17	0.37	0.60	0.50	0.72	0.12	0.09	0.15
Negative parental feelings, age 7	-->	CU traits, age 9	0.10	0.08	0.12	0.31	0.23	0.36	0.57	0.52	0.64	0.12	0.09	0.16

Negative parental feelings, age 9	-->	CU traits, age 12	0.11	0.09	0.13	0.77	0.70	0.87	0.13	0.01	0.21	0.10	0.06	0.14

Note. CU traits = Callous-unemotional traits; β = Standardized regression coefficient; A = Additive genetic influences; C = Shared environmental influences; E = Nonshared environmental influences; lCI = bootstrap 95% confidence intervals, lower bound; uCI = bootstrap 95% confidence intervals, upper bound;--> = One-way path (stability and cross-lagged paths); <-> = Two-way path (variance and cross-sectional covariance).

Figures

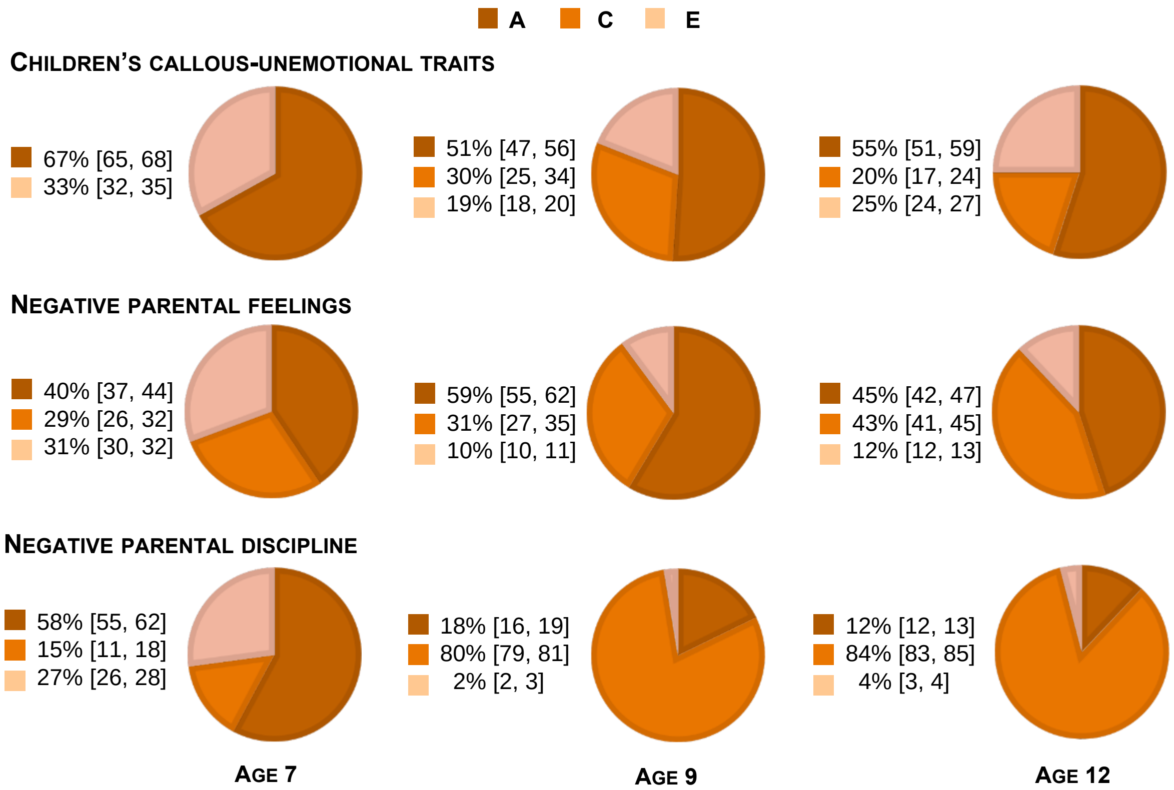


Figure 1. Univariate ACE estimates of children's CU traits, negative parental discipline, and negative parental feelings, reported by parents at child age 7, 9, and 12 years. A = Additive genetic influences; C = Shared environmental influences; E = Nonshared environmental influences.

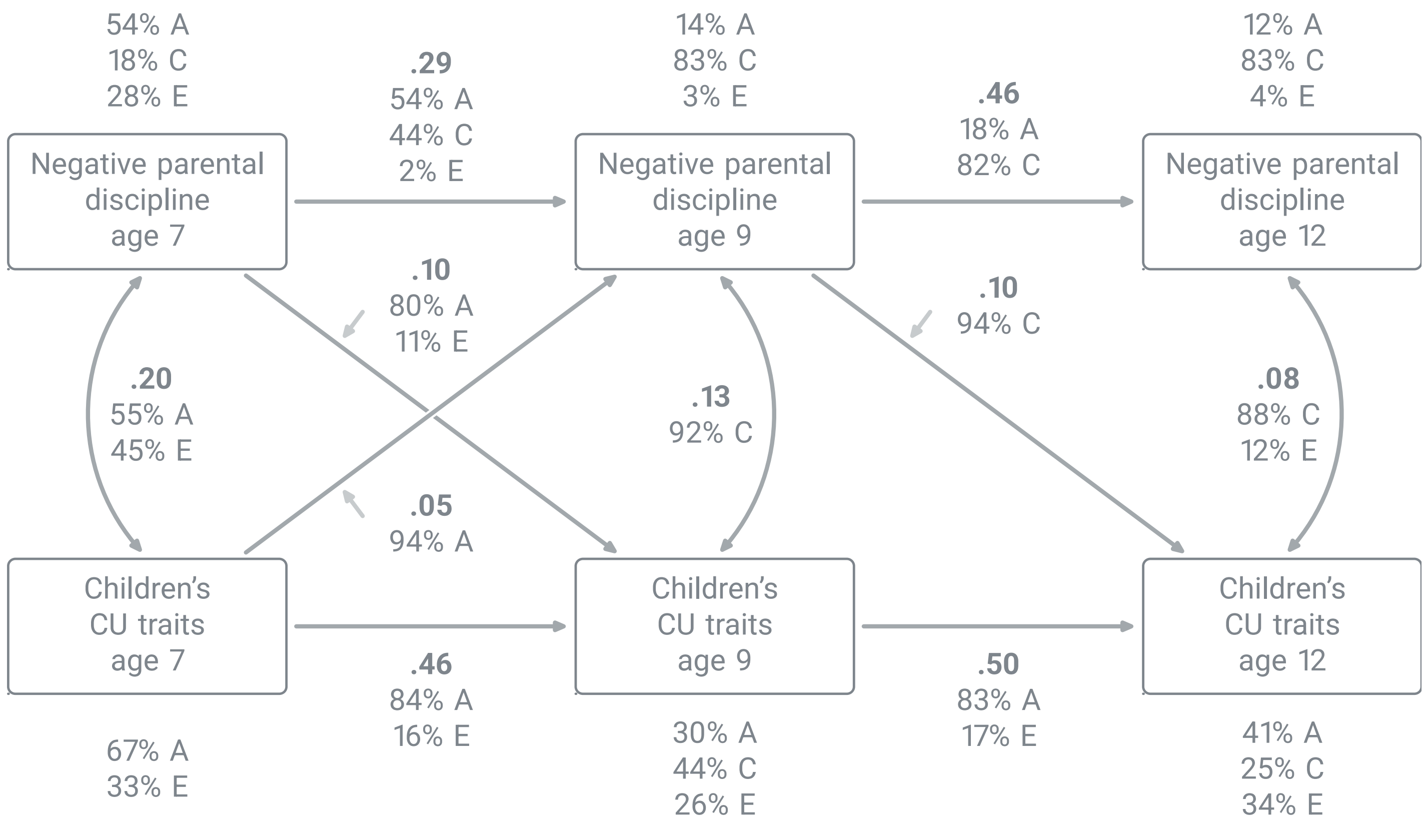


Figure 2. Cross-lagged twin Model 1, parent-reported negative parental discipline and parent-reported CU traits, child age 7, 9, and 12 years. A = Additive genetic influences; C = Shared environmental influences; E = Nonshared environmental influences. Non-significant paths are omitted. Confidence intervals are reported in Table 1.

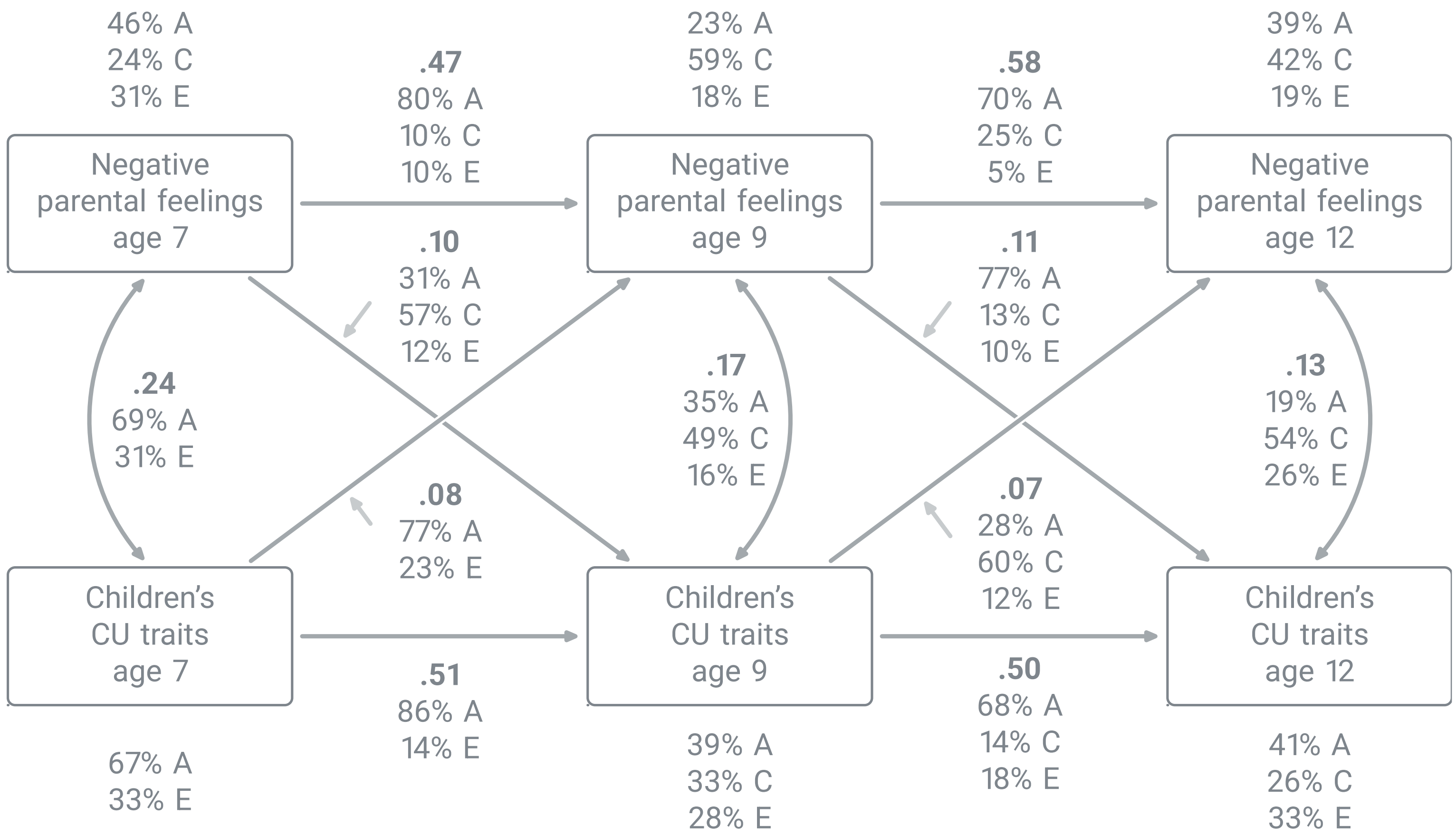


Figure 3. Cross-lagged twin Model 2, parent-reported negative parental feelings and parent-reported CU traits, child age 7, 9, and 12 years. A = Additive genetic influences; C = Shared environmental influences; E = Nonshared environmental influences. Confidence intervals are reported in Table 2.

Supplementary Materials

Supplementary Table S1. Items used in the Twins Early Development Study to measure callous-unemotional (CU) traits, negative parental discipline, and negative parental feelings at child age 7, 9, and 12 years.

	Age 7	Age 9	Age 12
Callous-unemotional traits	Items from the Strengths and Difficulties Questionnaire: 1. Helpful if someone is hurt, upset or feeling ill (R) 2. Considerate of other people's feelings (R) 3. Kind to younger children (R) 4. Has at least one good friend (R) Items from the Antisocial Process Screening Device: 5. Does not show feelings or emotions 6. Guilty when does something wrong (R) 7. Concerned to do well (R) Response options (for each twin separately): Here are some descriptions of children. Please tell us if you think that each statement is: • Certainly true • Somewhat true • Not true When you answer, think about their behavior over the last school year or so.	Same as age 7, except the questions asked about the children's behavior in the previous 6 months (vs. previous school year).	Same as age 9, except the questions asked about the children's behavior in the previous 3 months.
Negative parental discipline	Items: 1. Do you ever restrain or smack the ELDER twin? 2. Do you ever send the ELDER twin to her/his room or withdraw privileges? 3. Do you ever raise your voice or shout at the ELDER twin? 4. Do you ever ignore the ELDER twin when he/she is misbehaving? Question (for each item): • How often do you do this? ○ Never	Items: When my child misbehaves, I use the following methods: 1. Give a smack 2. Tell him/her off or shout at him/her 3. Explain or reason with him/her. (R) 4. Be firm or calm with him/her. (R) Response options (for each twin separately): • Rarely or never • Sometimes • Often	Same as age 9.

	○ Rarely ○ Sometimes ○ Often • Do you do this more or less often with the YOUNGER twin?		
Negative parental feelings	Items: 1. Do you ever feel impatient with the elder twin? 2. Does the elder twin ever make you feel frustrated? 3. Do you ever wish the elder twin would leave you alone? 4. Does the elder twin ever make you angry? 5. Do you generally feel quite happy about your relationship with the elder twin? (R) 6. Are you amused by the elder twin? (R) 7. Do you feel close to the elder twin? (R) Question (for each item): • How often do you feel this way? ○ Never ○ Rarely ○ Sometimes ○ Often • Do you feel this more or less often with the younger twin?	Items: Please tell us how often you experience the following common feelings: 1. I feel impatient with my child 2. I feel happy about my relationship with my child (R) 3. I am amused by my child (R) 4. I sometimes wish my child would leave me alone for a few minutes 5. My child makes me angry 6. I feel close to my child (R) 7. I feel frustrated by my child Response options (for each twin separately): • Rarely or never • Sometimes • Often	Same as age 9.

Note: For negative parental discipline and feelings at age 7, information on how twin-specific items and standardized scales were computed is available at teds.ac.uk/datadictionary/studies/derived_variables/7yr_derived_variables.htm#gdisp. The wording for items measuring CU traits in the parent and teacher questionnaires was equivalent except, at age 7, items the teacher questionnaire asked about the child’s behavior in the previous 6 months rather than in the previous school year.

Supplementary Table S2. Validity and reliability of the composite scores

		ω	lCI	uCI	ICC	lCI	uCI	χ^2 (df)	*df*	*p*
Age 7	Callous-unemotional traits	.58	.56	.61	.63	.62	.64	654.27	14	.000
	Negative parental discipline	.68	.65	.70	.72	.71	.73	13.79	2	.001
	Negative parental feelings	.69	.68	.75	.83	.82	.83	1531.50	14	.000
Age 9	Callous-unemotional traits	.63	.59	.65	.73	.73	.74	553.09	14	.000
	Negative parental discipline	.59	.54	.62	.74	.74	.75	286.97	2	.000
	Negative parental feelings	.73	.70	.76	.82	.81	.82	962.32	14	.000
Age 12	Callous-unemotional traits	.62	.56	.64	.71	.70	.71	613.65	14	.000
	Negative parental discipline	.56	.54	.60	.55	.54	.56	417.320	2	.000
	Negative parental feelings	.75	.71	.76	.83	.82	.83	2117.79	14	.000

Note. ω = Omega total, computed as the amount of reliable variance in the observed variables accounted for by a single factor (1); lCI = 95% Confidence interval, lower bound; uCI = 95% Confidence interval, upper bound; ICC = Intraclass correlation coefficients computed as per the two-way random effects model with single measures approach (2); χ^2 = chi-square test statistic for the Confirmatory Factor Analysis models extracting one factor from the selected items, estimated using default parameters in the lavaan R package (3); df = degrees of freedom (number of parameters estimated in each model), p = p-value associated with the chi-square test comparing each Confirmatory Factor Analysis model with corresponding baseline models representing the null hypothesis that items are uncorrelated. Across time points, the composite scores of CU traits and negative parental feelings consistently demonstrated good internal consistency and strong reliability, as well as reflecting a single underlying factor, as indicated by factor analysis. The composite score of negative parental discipline demonstrated good internal consistency at age 7, which declined slightly over subsequent assessments. Reliability was also good at ages 7 and 9 and declined at age 12. Nonetheless, factor analysis consistently supported the presence of a single factor underlying the negative discipline items. While the psychometric properties of the negative parental discipline score may not be considered consistently optimal, the complex nature of the construct being measured, combined with the results of the factor analysis and the robust estimation methods, lend support to the use of the composite score in this study.

References:

1. McDonald RP. Test theory: A unified treatment. Test Theory: A Unified Treatment. Taylor and Francis; 2013. 1–485 p.
2. Shrout PE, Fleiss JL. Intraclass correlations: Uses in assessing rater reliability. Psychological Bulletin. 1979;86(2):420–8.
3. Rosseel Y. lavaan : an R package for structural equation modeling. 2012;48(2):1–20.

Supplementary Table S3. Descriptive statistics

Variable	Twin age	*n*	*M*	*SD*	median	skewness	kurtosis	*SE*
Callous-unemotional traits	7	15178	0.44	0.29	0.43	0.68	0.45	0.00
	9	6625	0.39	0.27	0.29	0.80	0.73	0.00
	12	11457	0.33	0.26	0.29	0.95	1.12	0.00
Negative parental discipline	7	15212	0.01	0.99	-0.07	0.13	-0.01	0.01
	9	3363	2.40	1.22	2.00	0.45	-0.03	0.02
	12	11637	2.14	1.15	2.00	0.48	-0.16	0.02
Negative parental feelings	7	15273	0.00	0.99	-0.11	0.95	2.43	0.01
	9	6738	3.37	2.08	3.00	0.67	0.72	0.04
	12	11644	3.17	2.16	3.00	0.81	1.00	0.03

Note. The table reports the distribution of unstandardized mean scores for ease of interpretation, except for parent-reported negative parental discipline and negative parental feelings at child age 7, as only standardized scores were available in TEDS. The 7 items measuring callous-unemotional traits were rated on a 3-point Likert scale (0 = Not true, 1 = Somewhat true, 2 = Certainly true) and composite scores were computed as mean scores at all time points. At age 7, the 4 items measuring negative parental discipline and the 7 items measuring negative parental feelings were rated on a 4-point scale (0 = Never, 1 = Rarely, 2 = Sometimes, 3 = Often) and composite scores were computed as standardized mean scores. At age 9, items measuring negative parental discipline and feelings were scored on a 3-point scale (0 = Rarely or Never, 1 = Sometimes, 2 = Often) and composite scores were created as sum scores. At age 12, composite scores of negative parental discipline and feelings were computed as mean scores multiplied by the number of items in the scale (4 and 7). Higher values indicated higher levels of callous-unemotional traits and more negative parenting. Further details on the measures are available in the Methods section; items are reported verbatim in Supplementary Table S1.

Supplementary Table S4. Cross-trait phenotypic correlations

		Callous-unemotional traits								
		Age 7			Age 9			Age 12		
		r	lCI	uCI	*r*	lCI	uCI	*r*	lCI	uCI
Negative parental discipline	Age 7	0.19	0.18	0.21	0.17	0.15	0.2	0.17	0.15	0.19
	Age 9	0.13	0.11	0.16	0.22	0.20	0.24	0.19	0.17	0.22
	Age 12	0.11	0.10	0.13	0.15	0.13	0.18	0.19	0.18	0.21
Negative parental feelings	Age 7	0.24	0.22	0.26	0.19	0.17	0.22	0.19	0.17	0.21
	Age 9	0.19	0.16	0.21	0.26	0.24	0.29	0.24	0.21	0.27
	Age 12	0.17	0.15	0.19	0.21	0.18	0.23	0.32	0.30	0.34

Note. The table reports zero-order cross-variable Pearson correlations between parent-reported negative parental discipline and feelings and callous-unemotional traits at child age 7, 9, and 12. lCI = bootstrap 95% confidence intervals, lower bound; uCI = bootstrap 95% confidence intervals, upper bound.

Supplementary Table S5. Cross-lagged models by sex, parameter estimates

			Males			Females		
			β	lCI	uCI	β	lCI	uCI
Model 1								
Trait variance								
CU traits, age 7			1.00	1.00	1.00	1.00	1.00	1.00
CU traits, age 9			0.73	0.71	0.74	0.76	0.75	0.78
CU traits, age 12			0.69	0.67	0.70	0.76	0.75	0.78
Negative parental discipline, age 7			1.00	1.00	1.00	1.00	1.00	1.00
Negative parental discipline, age 9			0.90	0.88	0.90	0.90	0.90	0.89
Negative parental discipline, age 12			0.78	0.76	0.80	0.80	0.78	0.77
Trait stability								
CU traits, age 7	-->	CU traits, age 9	0.50	0.48	0.51	0.47	0.45	0.48
CU traits, age 9	-->	CU traits, age 12	0.54	0.52	0.55	0.46	0.44	0.47
Negative parental discipline, age 7	-->	Negative parental discipline, age 9	0.29	0.28	0.31	0.28	0.26	0.29
Negative parental discipline, age 9	-->	Negative parental discipline, age 12	0.46	0.44	0.47	0.45	0.44	0.47
Cross-sectional associations								
CU traits, age 7	<->	Negative parental discipline, age 7	0.20	0.19	0.21	0.16	0.15	0.17
CU traits, age 9	<->	Negative parental discipline, age 9	0.13	0.12	0.15	0.12	0.10	0.13
CU traits, age 12	<->	Negative parental discipline, age 12	0.07	0.06	0.08	0.07	0.06	0.09
Cross-lagged effects								
CU traits, age 7	-->	Negative parental discipline, age 9	0.09	0.07	0.11	0.11	0.09	0.12
CU traits, age 9	-->	Negative parental discipline, age 12	0.05	0.04	0.07	0.05	0.03	0.07
Negative parental discipline, age 7	-->	CU traits, age 9	0.09	0.07	0.11	0.08	0.07	0.10
Negative parental discipline, age 9	-->	CU traits, age 12	0.08	0.06	0.10	0.10	0.08	0.12
Model 2								

Trait variance								
CU traits, age 7			1.00	1.00	1.00	1.00	1.00	1.00
CU traits, age 9			0.73	0.71	0.75	0.76	0.74	0.77
CU traits, age 12			0.68	0.66	0.69	0.76	0.75	0.78
Negative parental feelings, age 7			1.00	1.00	1.00	1.00	1.00	1.00
Negative parental feelings, age 9			0.72	0.70	0.73	0.73	0.73	0.72
Negative parental feelings, age 12			0.63	0.62	0.65	0.65	0.59	0.58
Trait stability								
CU traits, age 7	-->	CU traits, age 9	0.49	0.47	0.50	0.46	0.44	0.47
CU traits, age 9	-->	CU traits, age 12	0.52	0.50	0.53	0.46	0.44	0.47
Negative parental feelings, age 7	-->	Negative parental feelings, age 9	0.49	0.48	0.51	0.50	0.48	0.51
Negative parental feelings, age 9	-->	Negative parental feelings, age 12	0.59	0.57	0.60	0.62	0.61	0.64
Cross-sectional associations								
CU traits, age 7	<->	Negative parental feelings, age 7	0.27	0.25	0.28	0.21	0.20	0.22
CU traits, age 9	<->	Negative parental feelings, age 9	0.12	0.11	0.14	0.11	0.10	0.12
CU traits, age 12	<->	Negative parental feelings, age 12	0.14	0.13	0.15	0.14	0.13	0.15
Cross-lagged effects								
CU traits, age 7	-->	Negative parental feelings, age 9	0.11	0.09	0.13	0.06	0.05	0.08
CU traits, age 9	-->	Negative parental feelings, age 12	0.05	0.03	0.06	0.06	0.05	0.07
Negative parental feelings, age 7	-->	CU traits, age 9	0.10	0.08	0.12	0.11	0.09	0.12
Negative parental feelings, age 9	-->	CU traits, age 12	0.13	0.11	0.15	0.10	0.08	0.11

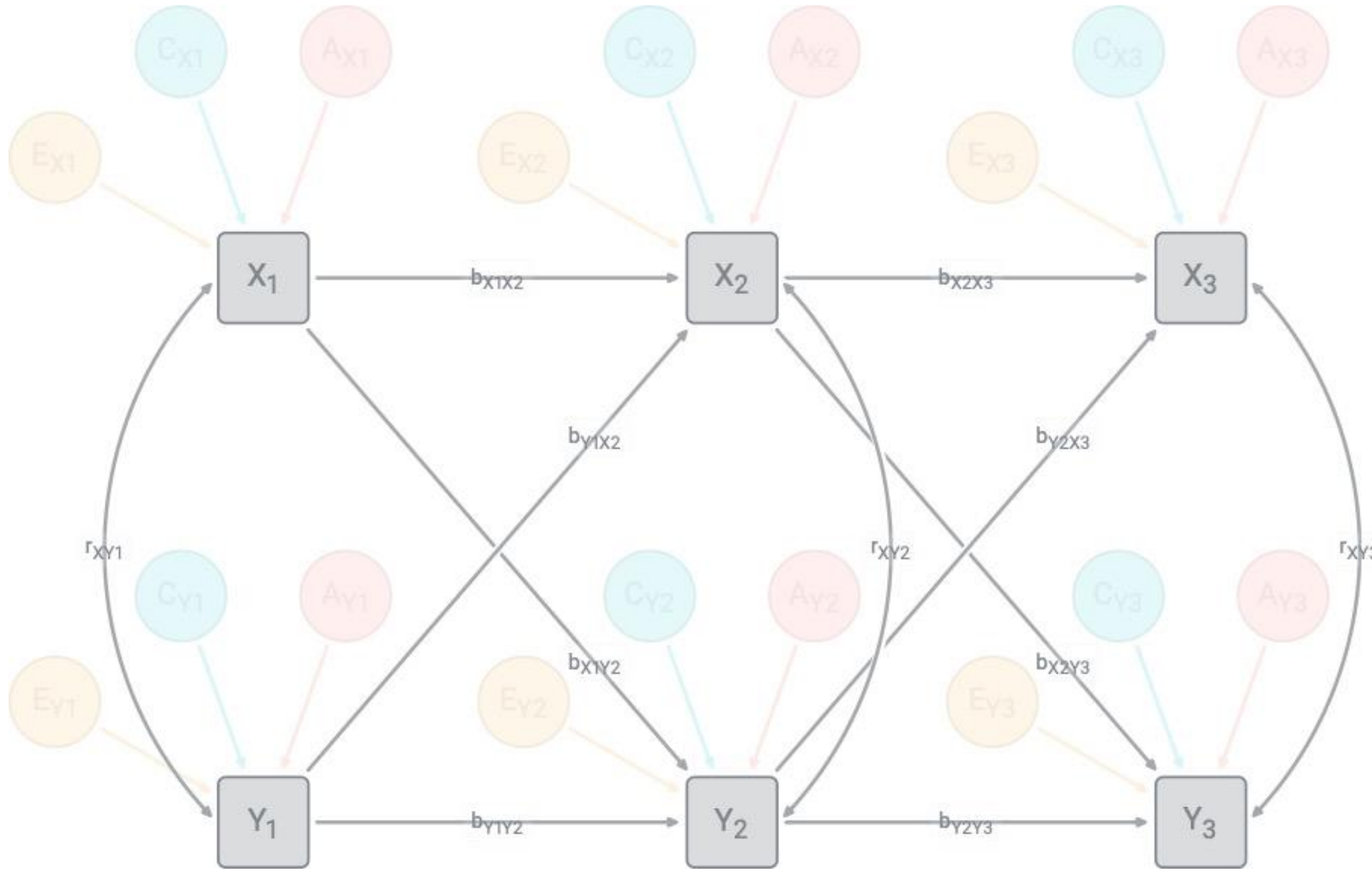
Note: CU traits = Callous-unemotional traits; β = Standardized regression coefficient; A = Additive genetic influences; C = Shared environmental influences; E = Nonshared environmental influences; lCI = bootstrap 95% confidence intervals, lower bound; uCI = bootstrap 95% confidence intervals, upper bound; --> = One-way path (stability and cross-lagged paths); <-> = Two-way path (variance and cross-sectional covariance). In both Models 1 and 2, phenotypic estimates were almost entirely consistent across sexes, as indicated by overlapping confidence intervals. Future studies are required to develop cross-lagged twin models that can examine sex differences in the etiology of longitudinal reciprocal effects.

Supplementary Table S6. Cross-lagged twin models with teacher-reported callous-unemotional traits, parameter estimates

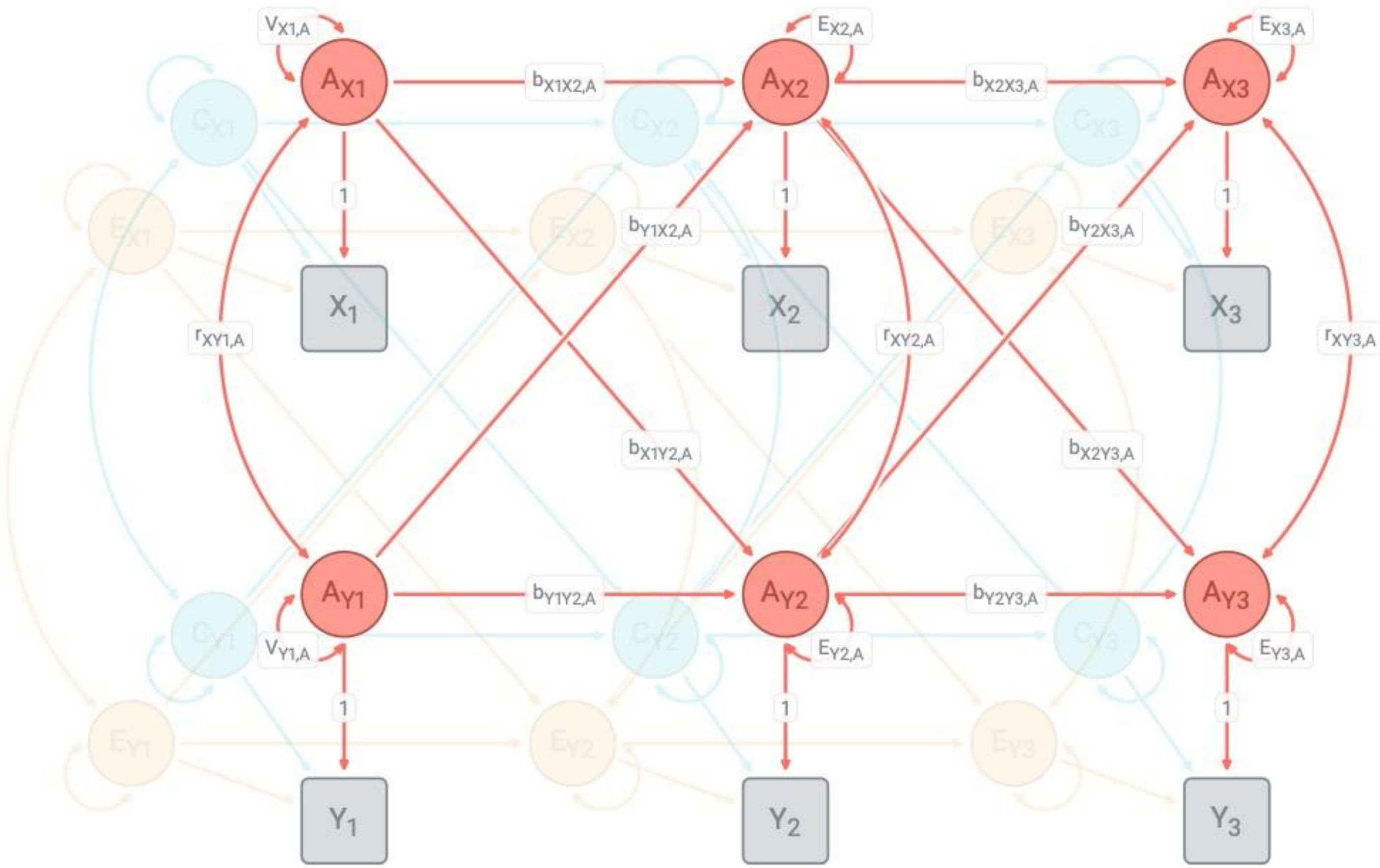
			β	CIl	CIu	A (%)	CIl	CIu	C (%)	CIl	CIu	E (%)	CIl	CIu
Model 1														
Trait variance														
Teacher-reported CU traits, age 7			1.00	1.00	1.00	0.72	0.71	0.73	0.00	0.00	0.00	0.28	0.27	0.29
Teacher-reported CU traits, age 9			0.60	0.56	0.64	0.35	0.29	0.40	0.00	0.00	0.00	0.65	0.60	0.71
Teacher-reported CU traits, age 12			0.81	0.79	0.83	0.55	0.53	0.58	0.00	0.00	0.00	0.45	0.42	0.47
Negative parental discipline, age 7			1.00	1.00	1.00	0.57	0.54	0.61	0.15	0.12	0.19	0.27	0.26	0.28
Negative parental discipline, age 9			0.90	0.88	0.91	0.13	0.11	0.14	0.84	0.83	0.85	0.03	0.03	0.03
Negative parental discipline, age 12			0.79	0.78	0.81	0.11	0.11	0.12	0.84	0.83	0.85	0.04	0.04	0.05
Trait stability														
Teacher-reported CU traits, age 7	-->	Teacher-reported CU traits, age 9	0.33	0.31	0.36	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Teacher-reported CU traits, age 9	-->	Teacher-reported CU traits, age 12	0.31	0.28	0.33	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Negative parental discipline, age 7	-->	Negative parental discipline, age 9	0.28	0.26	0.3	0.70	0.64	0.77	0.28	0.21	0.34	0.02	0.01	0.03
Negative parental discipline, age 9	-->	Negative parental discipline, age 12	0.45	0.42	0.47	0.19	0.17	0.21	0.81	0.79	0.83	0.00	0.00	0.00
Cross-sectional associations														
Teacher-reported CU traits, age 7	<->	Negative parental discipline, age 7	0.18	0.17	0.19	0.87	0.83	0.92	0.00	0.00	0.00	0.13	0.08	0.17
Teacher-reported CU traits, age 9	<->	Negative parental discipline, age 9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Teacher-reported CU traits, age 12	<->	Negative parental discipline, age 12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cross-lagged effects														
Teacher-reported CU traits, age 7	-->	Negative parental discipline, age 9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Teacher-reported CU traits, age 9	-->	Negative parental discipline, age 12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Negative parental discipline, age 7	-->	Teacher-reported CU traits, age 9	0.04	0.02	0.06	0.55	0.50	0.58	0.45	0.42	0.48	0.00	0.00	0.00
Negative parental discipline, age 9	-->	Teacher-reported CU traits, age 12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Model 2														
Trait variance														
Teacher-reported CU traits, age 7			1.00	1.00	1.00	0.72	0.71	0.73	0.00	0.00	0.00	0.28	0.27	0.29

Teacher-reported CU traits, age 9			0.78	0.75	0.80	0.52	0.48	0.55	0.00	0.00	0.00	0.48	0.45	0.52
Teacher-reported CU traits, age 12			0.81	0.79	0.83	0.56	0.53	0.58	0.00	0.00	0.00	0.44	0.42	0.47
Negative parental feelings, age 7			1.00	1.00	1.00	0.42	0.42	0.43	0.28	0.25	0.29	0.31	0.29	0.32
Negative parental feelings, age 9			0.57	0.54	0.60	0.83	0.81	0.84	0.00	0.00	0.00	0.17	0.16	0.19
Negative parental feelings, age 12			0.59	0.56	0.60	0.35	0.31	0.39	0.45	0.42	0.49	0.19	0.18	0.21
Trait stability														
Teacher-reported CU traits, age 7	-->	Teacher-reported CU traits, age 9	0.35	0.33	0.38	0.92	0.91	0.94	0.00	0.00	0.00	0.08	0.02	0.14
Teacher-reported CU traits, age 9	-->	Teacher-reported CU traits, age 12	0.28	0.26	0.3	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Negative parental feelings, age 7	-->	Negative parental feelings, age 9	0.49	0.48	0.50	0.92	0.92	0.93	0.00	0.00	0.00	0.08	0.05	0.10
Negative parental feelings, age 9	-->	Negative parental feelings, age 12	0.51	0.49	0.53	0.93	0.92	0.94	0.00	0.00	0.00	0.07	0.07	0.07
Cross-sectional associations														
Teacher-reported CU traits, age 7	<->	Negative parental feelings, age 7	0.14	0.12	0.15	0.86	0.81	0.93	0.00	0.00	0.00	0.14	0.08	0.20
Teacher-reported CU traits, age 9	<->	Negative parental feelings, age 9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Teacher-reported CU traits, age 12	<->	Negative parental feelings, age 12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cross-lagged effects														
Teacher-reported CU traits, age 7	-->	Negative parental feelings, age 9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Teacher-reported CU traits, age 9	-->	Negative parental feelings, age 12	0.08	0.04	0.08	0.83	0.77	0.91	0.00	0.00	0.00	0.17	0.09	0.23
Negative parental feelings, age 7	-->	Teacher-reported CU traits, age 9	0.03	0.01	0.05	0.60	0.52	0.80	0.35	0.16	0.35	0.05	0.04	0.05
Negative parental feelings, age 9	-->	Teacher-reported CU traits, age 12	0.09	0.08	0.10	0.87	0.77	0.97	0.00	0.00	0.00	0.13	0.12	0.13

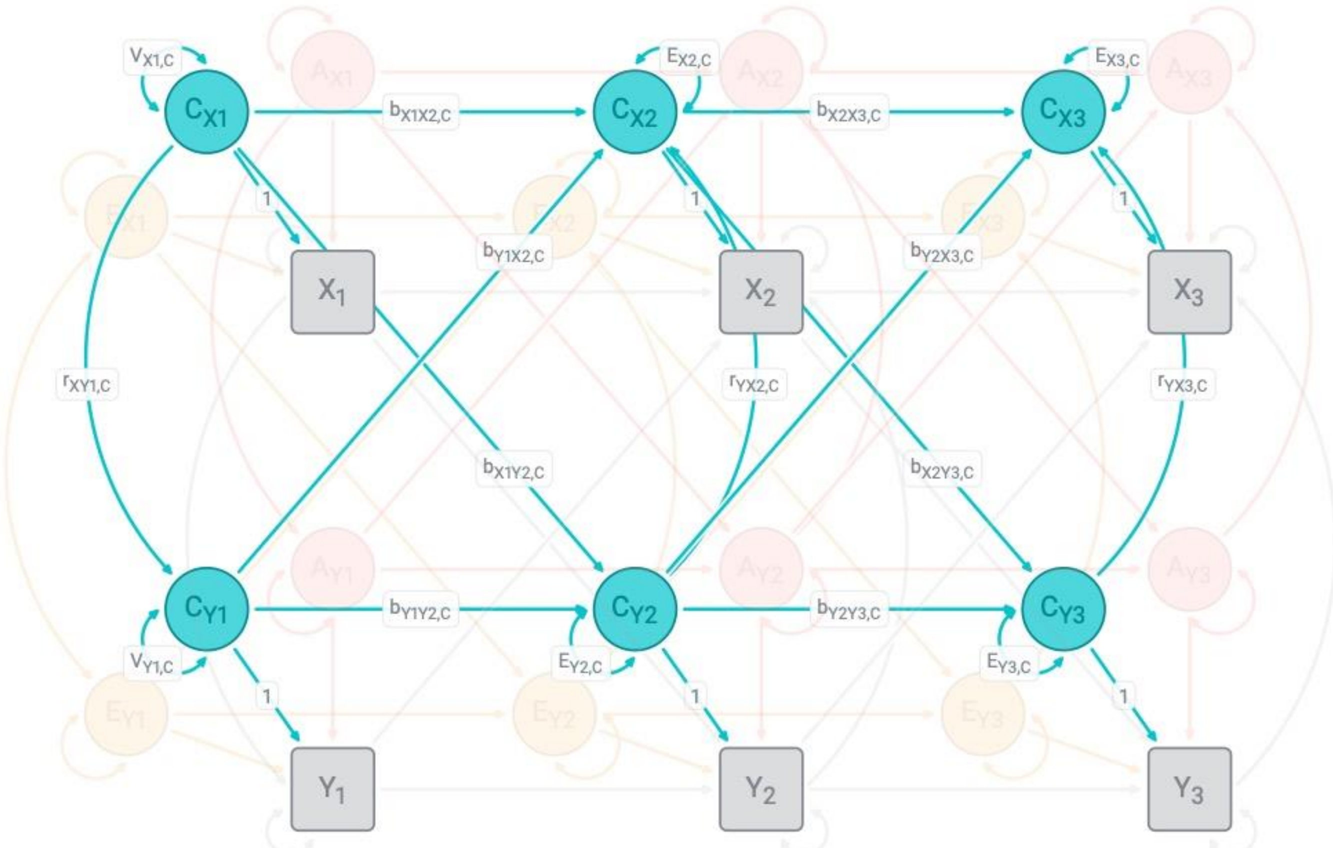
Note: CU traits = Callous-unemotional traits; β = Standardized regression coefficient; A = Additive genetic influences; C = Shared environmental influences; E = Nonshared environmental influences; lCI = bootstrap 95% confidence intervals, lower bound; uCI = bootstrap 95% confidence intervals, upper bound; --> = One-way path (stability and cross-lagged paths); <-> = Two-way path (variance and cross-sectional covariance). Teacher reports of CU traits demonstrated moderate consistency with parent reports at each time point (r = .22, .24, .21), as expected since they capture different aspects of CU traits relative to parent perceptions, which were the focus of this study. Estimates in the cross-lagged twin models using teacher reports were broadly in alignment with the corresponding models using parent reports, albeit with smaller phenotypic estimates. In particular, cross-lagged effects were very small or non-significant. These differences can be explained by informant discrepancy (i.e., differences in the observations of parents and teachers leading to different assessments of children's traits and associations with negative parenting). This finding underscores the potential role of contextual factors and the specific dynamics between different raters in shaping the relationship between negative parenting and CU traits.



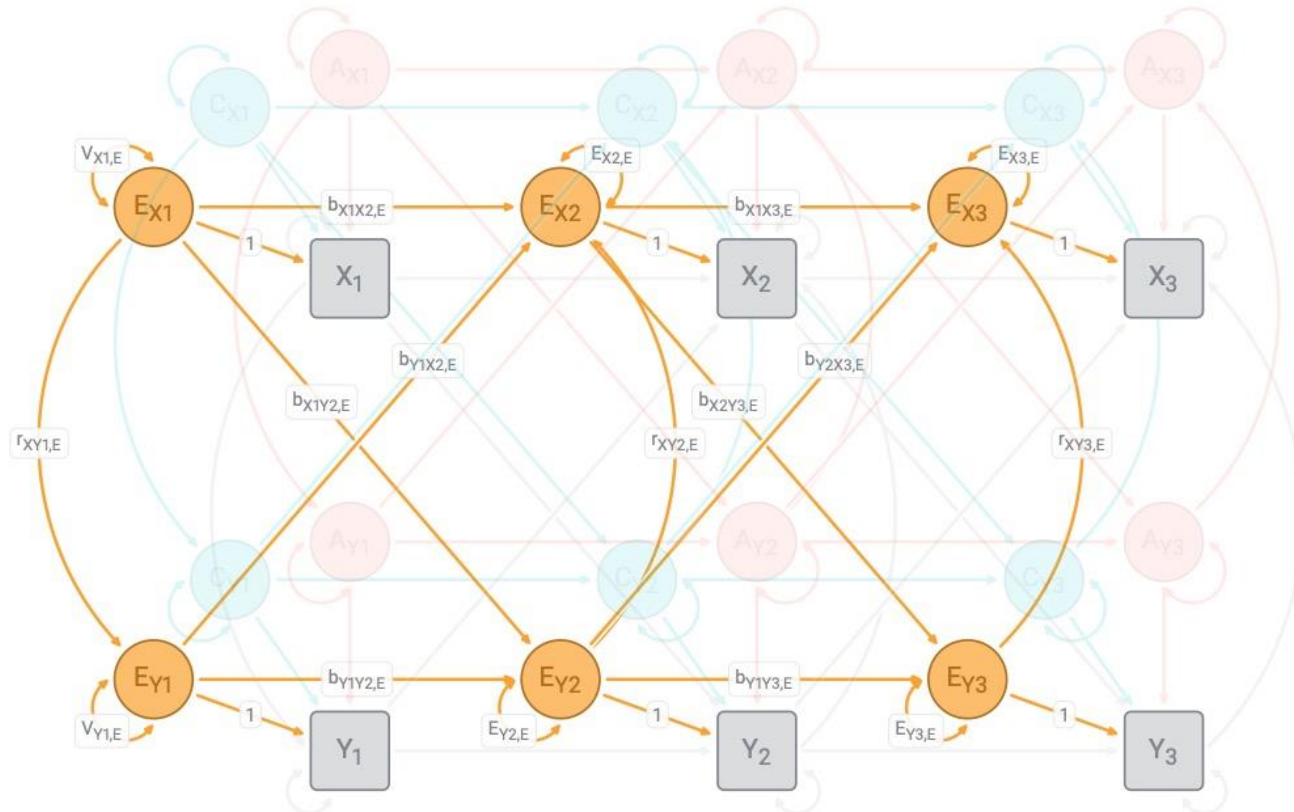
Supplementary Figure S1. Representation of the cross-lagged ACE model, phenotypic paths. X1, X2, X3 and Y1, Y2, Y3 = Observed variables X and Y, respectively, at times (measurements) 1, 2, and 3; V_{X1}, E_{X2}, E_{X3} and V_{Y1}, E_{Y2}, E_{Y3} = Variance in X and Y, respectively, at times 1, 2, and 3; b_{X1X2}, b_{Y1Y2} , b_{X2X3} , b_{Y2Y3} = Longitudinal stability in X and Y, respectively, between times 1 and 2, and then between times 2 and 3; r_{XY1} , r_{XY2} , r_{XY3} = Cross-sectional association between X and Y at times 1, 2, and 3; b_{X1Y2} , b_{X2Y3} = Cross-lagged path from X at time 1 to Y at time 2, and then from X at time 2 to Y at time 3; b_{Y1X2} , b_{Y2X3} = Cross-lagged path from Y at time 1 to X at time 2, and then from Y at time 2 to X at time 3.



Supplementary Figure S2. Representation of the cross-lagged ACE model, A paths. $V_{X1,A}$, $V_{X2,A}$, $V_{X3,A}$ and $V_{Y1,A}$, $V_{Y2,A}$, $V_{Y3,A}$ = Additive genetic contribution to the variance in X and Y, respectively at times 1, 2, and 3; $b_{X1X2,A}$, $b_{Y1Y2,A}$, $b_{X2X3,A}$, $b_{Y2Y3,A}$ = Additive genetic contribution to the longitudinal stability in X and Y, respectively, between times 1 and 2, and then between times 2 and 3; $r_{XY1,A}$, $r_{XY2,A}$, $r_{XY3,A}$ = Additive genetic contribution to the cross-sectional association between X and Y at times 1, 2, and 3; $b_{X1Y2,A}$, $b_{X2Y3,A}$ = Additive genetic contribution to the cross-lagged path from X at time 1 to Y at time 2, and then from X at time 2 to Y at time 3; $b_{Y1X2,A}$, $b_{Y2X3,A}$ = Additive genetic contribution to the cross-lagged path from Y at time 1 to X at time 2, and then from Y at time 2 to X at time 3.



Supplementary Figure S3. Representation of the cross-lagged ACE model, C paths. $V_{X1,C}$, $V_{X2,C}$, $V_{X3,C}$ and $V_{Y1,C}$, $V_{Y2,C}$, $V_{Y3,C}$ = Shared environmental contribution to the variance in X and Y, respectively at times 1, 2, and 3; $b_{X1X2,C}$, $b_{Y1Y2,C}$, $b_{X2X3,C}$, $b_{Y2Y3,C}$ = Shared environmental contribution to the longitudinal stability in X and Y, respectively, between times 1 and 2, and then between times 2 and 3; $r_{XY1,C}$, $r_{XY2,C}$, $r_{XY3,C}$ = Shared environmental contribution to the cross-sectional association between X and Y at times 1, 2, and 3; $b_{X1Y2,C}$, $b_{X2Y3,C}$ = Shared environmental contribution to the cross-lagged path from X at time 1 to Y at time 2, and then from X at time 2 to Y at time 3; $b_{Y1X2,C}$, $b_{Y2X3,C}$ = Shared environmental contribution to the cross-lagged path from Y at time 1 to X at time 2, and then from Y at time 2 to X at time 3.



Supplementary Figure S4. Representation of the cross-lagged ACE model, C paths. $V_{X1,E}$, $V_{X2,E}$, $V_{X3,E}$ and $V_{Y1,E}$, V_{Y2},E, $V_{Y3,E}$ = Nonshared environmental contribution to the variance in X and Y, respectively at times 1, 2, and 3; $b_{X1X2,E}$, $b_{Y1Y2,E}$, $b_{X2X3,E}$, $b_{Y2Y3,E}$ = Nonshared environmental contribution to the longitudinal stability in X and Y, respectively, between times 1 and 2, and then between times 2 and 3; $r_{XY1,E}$, $r_{XY2,E}$, $r_{XY3,E}$ = Nonshared environmental contribution to the cross-sectional association between X and Y at times 1, 2, and 3; $b_{X1Y2,E}$, $b_{X2Y3,E}$ = Nonshared environmental contribution to the cross-lagged path from X at time 1 to Y at time 2, and then from X at time 2 to Y at time 3; $b_{Y1X2,E}$, $b_{Y2X3,E}$ = Nonshared environmental contribution to the cross-lagged path from Y at time 1 to X at time 2, and then from Y at time 2 to X at time 3.