**AsPredicted registration:**

1. **Have any data been collected for this study already? (optional)**

Yes, data for this study will be drawn from the Adolescent Brain Cognitive Development (ABCD) study. We will examine data drawn from the baseline assessment and three yearly follow-up assessments for a total of four assessment periods. Data from the ABCD study have been used in numerous past publications, all of which can be found at <https://abcdstudy.org/publications/>.

We highlight select publications most relevant to the focal analyses of our planned project. The following publications all focused on modeling the hierarchical structure of psychopathology symptoms using items from the Child Behavior Checklist (CBCL):

1. ﻿ Michelini, G., Barch, D. M., Tian, Y., Watson, D., Klein, D. N., & Kotov, R. (2019). Delineating and validating higher-order dimensions of psychopathology in the Adolescent Brain Cognitive Development (ABCD) study. Translational Psychiatry, 9(1), 21–25. <https://doi.org/10.1038/s41398-019-0593-4>

Michelini and colleagues (2019) conducted a “bass-ackwards” factor analysis using 102 items of the parent-report CBCL (after creating composites of highly correlated items and dropping items with low endorsement). At the most specific level of the hierarchy, the authors identified five factors. These five factors were labeled externalizing, neurodevelopmental, internalizing, somatoform, and detachment. The authors also examined the relations between the five identified factors and various external outcomes: ﻿history of developmental delays in motor and speech, family conflict, number of friends, school connectedness, average grades, crystalized and fluid intelligence composites, utilization of physical and mental health services, and medication use. Michelini and colleagues focused solely on data derived from the ABCD baseline assessment.

1. Moore, T. M., Kaczkurkin, A. N., Durham, E. L., Jeong, H. J., McDowell, M. G., Dupont, R. M., Applegate, B., Tackett, J. L., Cardenas-Iniguez, C., Kardan, O., Akcelik, G. N., Stier, A. J., Rosenberg, M. D., Hedeker, D., Berman, M. G., & Lahey, B. B. (2020). Criterion validity and relationships between alternative hierarchical dimensional models of general and specific psychopathology. Journal of Abnormal Psychology, 129(7), 677–688. <https://doi.org/10.1037/abn0000601>

Moore and colleagues (2020) also examined the structure of the CBCL items and compared bifactor and second-order (i.e., hierarchical) models to one another. The authors conducted a series of exploratory structural equation models and retained CBCL items with loadings ≥.40 for subsequent analyses. The authors reported results for 2-, 3-, and 4-factor solutions. In the 4-factor solution, the factors were labeled externalizing, attention deficit hyperactivity disorder (ADHD), internalizing, and somatic. These four factors were also compared with external criteria which included cognitive function, dimensions of impulsivity, prosocial behavior, suicidal and self-harming behavior, and three measures of functional impairment (receiving mental health services, school detentions or suspensions, and enrollment in any form of special education).

1. ﻿Clark, D. A., Hicks, B. M., Angstadt, M., Rutherford, S., Taxali, A., Hyde, L., Weigard, A., Heitzeg, M. M., & Sripada, C. (2023). The General Factor of Psychopathology in the Adolescent Brain Cognitive Development (ABCD) Study: A Comparison of Alternative Modeling Approaches. Clinical Psychological Science, 1–23.

Clark and colleagues (2023) conducted item- and scale-based factor analyses using items and subscales from the CBCL. Factors derived from the item-based analyses (examined with a series of hierarchical and bifactor models; 14 distinct models in total) were interpretable until five factors were extracted. The four factors that reliably emerged from these analyses were described as externalizing problems, attention problems, internalizing problems, and somatic problems.

Collectively, these three studies report results that overlap with some of our proposed analyses. First, these studies provided extensive data on the hierarchical structure of psychopathology using parent-reported CBCL data. Our primary analyses will also focus on parent-reported CBCL data. Second, each of these studies examined how factor-analytically derived dimensions of psychopathology related to clinical and functional outcomes at baseline in the ABCD data. We also plan to conduct similar analyses examining the hierarchical structure of externalizing behavior, specifically, and plan to use clinical and psychosocial outcomes as criterion measures.

Thus, the information that is known to us and relevant to our project prior to conducting our analyses is as follows: an externalizing dimension can be reliably identified using baseline parent-reported CBCL data. A second dimension that contains disinhibitory content can also be identified using baseline parent-reported CBCL data. This second dimension is labeled somewhat differently across studies, with Michelini et al. (2019) labeling it a neurodevelopmental factor, while Moore et al. (2020) and Clark et al. (2023) labeled the factor as an ADHD factor or an attention problems factor, respectively. We also know that the externalizing factor identified across these studies most strongly relates to the neurodevelopmental/ADHD/attention problem factor (*r* range = .57-.59). Lastly, there are reliable empirical associations between the externalizing dimensions assessed at baseline and various clinical and psychosocial outcomes.

Our primary analyses will extend these past results in a few important ways. First, we will focus specifically on the externalizing superspectrum with the aim of elucidating its hierarchical structure (i.e., examining broad-based externalizing and then more specific antagonistic and disinhibitory spectra, consistent with the Hierarchical Taxonomy of Psychopathology, or HiTOP). Second, while we also will examine baseline assessment data from the ABCD study, we will expand our analyses to include data collected at the 1-, 2-, and 3-year follow-up assessments. Because we will be examining CBCL scores longitudinally, we will be able to examine within-individual changes in latent externalizing traits and assess how these changes relate to meaningful clinical and psychosocial outcomes assessed at each time point.

1. **What's the main question being asked or hypothesis being tested in this study? (optional)**

Growing research highlights the importance of examining externalizing psychopathology dimensionally. In adults, evidence supports the validity and utility of disaggregating the externalizing superspectrum into antagonistic and disinhibited spectra. However, less work has examined these constructs in youth, limiting our knowledge of the developmental processes underlying trajectories of externalizing psychopathology.

To address this gap, the proposed study will use data from a large, representative developmental study of youth to examine the longitudinal stability and validity of the externalizing, antagonistic, and disinhibited spectra. Data will be drawn from the baseline and three yearly follow-up assessments of the Adolescent Brain Cognitive Development (ABCD)TM study (N=11,875; Mage=9.51; 48% girls; 57% White; 15% Black; 20% Hispanic/Latino/a).

We will use factor analytic techniques and latent difference score models to address four research aims: 1) identify the hierarchical structure of externalizing psychopathology in the ABCD study 2) assess the longitudinal measurement invariance of externalizing, antagonism, and disinhibition spectra; 3) examine baseline levels and within-individual change in latent spectra, and their respective associations with clinically relevant outcomes (e.g., psychopathology, psychosocial functioning) and 4) examine how risk and resilience factors (e.g., parenting style, neighborhood) impact baseline levels and within-individual change in latent spectra.

We will use parent-reported scores from the CBCL for our primary analyses, and when possible, will examine outcomes reported by both parents and youth. Collectively, the results from the proposed study will address the validity and utility of disaggregating the externalizing superspectrum in youth during a developmentally sensitive window.

Our primary hypotheses (where applicable) are as follows:

**Aim 1: Identify the hierarchical structure of externalizing psychopathology in the ABCD study.**

*Hypothesis 1a:* We hypothesize that antagonistic and disinhibited spectra can be identified at more fine-grained levels of the hierarchy with the same items that have been shown to comprise a broad-based externalizing superspectrum (i.e., the items with primary loadings on the broad-based externalizing factor in Michelini et al., 2019).

*Hypothesis 1b:* If parallel analysis and the minimum average partial correlation test (MAP) suggest a relatively large number of factors can be extracted from the CBCL items (e.g., 5 or more), we expect that the antagonistic and disinhibited dimensions will emerge relatively early on in the factor extraction process (e.g., at level 2 or level 3) given that they reflect relatively broad dimensions of externalizing psychopathology.

**Aim 2: Assess the longitudinal measurement invariance of externalizing, antagonism, and disinhibition spectra.**

These analyses will be exploratory in nature, and we have no *a priori* hypotheses about whether criteria for strong measurement invariance will be satisfied.

**Aim 3: Examine baseline levels and within-individual change in latent spectra, and their respective associations with clinically relevant outcomes (e.g., psychopathology, psychosocial functioning).**

*Hypothesis 2a:* Based on past longitudinal evidence regarding externalizing traits and behaviors (e.g., Miner & Clark-Stewart, 2008; Bongers et al., 2004), we hypothesize that latent levels of externalizing dimensions (broad-based externalizing, antagonistic externalizing, and disinhibited externalizing) will decrease over time as indicated by a significant negative slope factor, which represents the rate of constant change in our latent change score models.

*Hypothesis 2b:* There will be significant individual differences in the latent slope factors and baseline intercepts highlighting that youth differ from one another both in the degree of constant change in latent externalizing dimensions over time and in mean levels of latent externalizing dimensions at baseline.

*Hypothesis 2c:* Baseline externalizing scores (broad-based externalizing, antagonistic externalizing, and disinhibited externalizing) and within-individual change in these scores (both assessed with latent factors) will be positively associated with all clinical outcomes as assessed by the KSADS (detailed below). However, we expect larger effect sizes between the latent factors and externalizing symptoms (i.e., conduct disorder, substance use, and oppositional defiant disorder) or symptoms of neurodevelopmental disorders (i.e., ADHD) compared to internalizing symptoms (i.e., depression and anxiety disorders).

*Hypothesis 2d:* We hypothesize that latent broad-based externalizing will be negatively related to prosocial behavior and positively related to aggression and impulsivity.

*Hypothesis 2e:* Evidence of discriminant findings will emerge for the antagonistic and disinhibited externalizing spectra. Specifically, we hypothesize that antagonistic externalizing will have larger effect sizes with prosocial behavior and aggression compared to disinhibited externalizing. Meanwhile, disinhibited externalizing will have a larger effect size for the impulsivity and substance use outcomes.

**Aim 4: Examine how risk and resilience factors across multiple domains (e.g., neighborhood, school, peer, family) impact baseline levels and within-individual change in latent externalizing spectra.**

*Hypothesis 3a:* We hypothesize that we will find the following positive associations: neighborhood safety and higher family conflict will have a positive association with baseline levels of externalizing dimensions (i.e., a significant regression path with latent intercepts at T1) and will be positively associated with the latent slope factor, meaning youth that live in less safe neighborhoods and experience more family conflict will show *less* of a decrease in externalizing dimensions over time.

We hypothesize that we will find the following negative associations: peer relationships (i.e., more friends) and positive school environment will have a negative association with baseline externalizing dimensions (i.e., a significant negative regression path with latent intercepts at T1) and a negative association with the latent slope factor, meaning youth reporting more friendships and more positive school environments will show a *greater* decrease in externalizing dimensions over time.

*Hypothesis 3b:* We hypothesize that the risk and resilience factors will act as broad-based risk or resilience factors. Specifically, we do not expect discriminant associations to emerge depending on which externalizing dimension is examined.

1. **Describe the key independent and dependent variable(s) specifying how they will be measured. (optional)**

*Externalizing Psychopathology*

**Externalizing Dimensions (Parent-Report).** We will assess externalizing psychopathology using the parent-reported CBCL, which was administered at all 4 assessments (baseline, T1, T2, T3). We will use CBCL items first identified in the ABCD baseline data by Michelini et al. (2019). In their five-factor solution, the authors identified two factors, an externalizing factor and a neurodevelopmental factor (this factor was termed the ADHD factor in Moore et al., 2020 and attention problems in Clark et al., 2023). These two factors had a total of 44 items/item composites (noted with an \*) that showed either primary loadings on one of the factors or loaded on both factors without a clear primary loading (e.g., the item “Impulsive or acts without thinking” had a loading of .49 on both the externalizing and neurodevelopmental factors). Table 1 below provides the specific CBCL items that will be used for our analyses.

|  |  |
| --- | --- |
| **Table 1** | |
| **Externalizing Factor** | **Neurodevelopmental/ADHD Factor** |
| Argues a lot | Acts too young for his/her age |
| Cruel to animals | Fails to finish things he/she starts |
| Cruelty, bullying, or meanness to others | Can't get his/her mind off certain thoughts; obsessions |
| Demands a lot of attention | Confused or seems to be in a fog |
| Doesn't seem to feel guilty after misbehaving | Daydreams or gets lost in his/her thoughts |
| Easily jealous | Gets hurt a lot, accident prone |
| Feels others are out to get him/her | Nervous movements or twitching |
| Gets in many fights | Poor schoolwork |
| Hangs around with others who get in trouble | Poorly coordinated or clumsy |
| Lying or cheating | Prefers being with younger kids |
| Runs away from home | Repeats certain acts over and over; compulsions |
| Screams a lot | Stares blankly |
| Sets fires | Strange ideas |
| Showing off or clowning | Talks too much |
| Stubborn, sullen, or irritable | Composite (Distracted/Hyperactive)\* |
| Sudden changes in mood or feelings | Impulsive or acts without thinking |
| Sulks a lot |  |
| Suspicious |  |
| Swearing or obscene language |  |
| Teases a lot |  |
| Temper tantrums or hot temper |  |
| Thinks about sex too much |  |
| Whining |  |
| Composite (Attacks/Threatens)\* |  |
| Composite (Destroys)\* |  |
| Composite (Disobeys rules)\* |  |
| Composite (Peer problems)\* |  |
| Composite (Steals)\* |  |

*Clinical Outcomes*

**Diagnostic Constructs (Parent- and Youth-Report).** Clinical outcomes will be assessed using clinician ratings of parent- and youth-reported modules of the Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS-5). Clinical outcomes will be assessed using dimensional symptom counts for the following externalizing, neurodevelopmental, and internalizing diagnostic constructs: conduct disorder, oppositional defiant disorder, substance use disorders, ADHD, major depressive disorder, suicidality/self-harm, generalized anxiety disorder, and social anxiety disorder. The symptom is indicated as being present (1) or not present (0), and symptoms will be summed such that higher scores indicate more symptoms endorsed for the diagnostic construct.

This semi-structured diagnostic interview was administered to parents at each assessment (T1-T4) and parents completed all KSADS-5 modules. Youth completed specific KSADS-5 modules at each time point. At T1, youth completed the mood disorder, social anxiety, generalized anxiety disorder, suicidality, and sleep modules. At T2 and T4, youth completed the suicidality and alcohol and drug use disorder modules. At T3, youth completed the mood disorder, social anxiety disorder, generalized anxiety disorder, sleep, and suicidality modules along with the eating disorder, conduct disorder, and alcohol and drug use disorder modules.

Thus, parent-reported clinical outcomes (symptoms of conduct disorder, oppositional defiant disorder, substance use disorders, ADHD, major depressive disorder, suicidality/self-harm, generalized anxiety disorder, and social anxiety disorder) will be available for analyses at each time point and youth-reported information for the same clinical outcomes will also be examined when available (see above).

**Receipt of Mental Health Services (Parent-Report).** The KSADS-5 also asks parents to report whether youth ever received mental health or substance abuse services. Response options were 0 (no), 1 (yes), and 2 (not sure). We will examine the outcome using a dichotomous 0/1 (no/yes) score. Receipt of mental health service was assessed at each assessment (T1-T4).

*Psychosocial Functioning*

**Prosocial Behavior (Youth-Report).** Prosocial behavior will be assessed using the 3-items from the youth-reported Strengths and Difficulties Questionnaire (SDQ) (“*I try to be nice to other people*”; “*I care about their feelings*”; “*I offer to help others*”). Items are rated on a 3-point scale ranging from 0 (*not true*) to 2 (*certainly true*) and summed such that higher scores represent increased levels of prosocial behavior. Prosocial behavior was assessed at T1-T4.

**Aggressive Behavior (Youth-Report).** Aggressive behavior will be assessed using the aggressor scale of the youth-reported Peer Experiences Questionnaire (PEQ). The PEQ aggressor scale includes 9-items that assess relational (e.g., “*I did not invite a kid to a party or other social event even though I knew the kid wanted to go*”) and overt aggression (e.g., “*I chased a teen like I was really trying to hurt him or her*”). Items are rated on a 5-point scale ranging from 1 (*never*) to 5 (*a few times a week*) and are summed such that higher scores present increased aggressive behavior. Aggressive behavior was assessed at T3 and T4.

**Impulsivity (Youth-Report).** Impulsivity was assessed using the youth-reported Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale (UPPS-P for Children Short Form – ABCD version). The scale contained 20 items assessing impulsivity (e.g., “*I like to stop and think about things before I do them.*”) and includes 5 subscales: negative urgency, positive urgency, Lack of Perseverance, Lack of Planning, and Sensation Seeking. Items were rated on a 4-point scale from 1 (*not at all like me*) to 4 (*very much like me*) and summed such that higher scores represent higher impulsivity. Impulsivity was assessed at T1 and T3.

*Risk and Resilience Factors*

**Neighborhood Safety (Parent-Report).** Neighborhood safety was assessed with three items from the PhenX Toolkit: “*My neighborhood is safe from crime*”, “*I feel safe walking in my neighborhood, day or night*.”, and “*Violence is not a problem in my neighborhood”.* Parents/caregivers were instructed to think about their neighborhood as the area within about a 20-minute walk (or about a mile) from their home.” Items were rated scale from 1 (*strongly disagree*) to , 5 (*strongly agree*) and summed to create a total score, with higher scores indicating a less safe neighborhood. Neighborhood safety was assessed T1-T4.

**School connectedness (Youth-Report).** School connectedness was assessed using 12 items from the youth-reported the School Risk and Protective Factors Survey. Youth were asked to rate their classroom environment, teachers, personal involvement, and academic goals on a scale from X to X. Items were summed to create a total score, with higher scores indicating more school connectedness. School connectedness was assessed T1-T4.

**Peer relationships (Youth-Report).** Peer relationships were assessed using a 4-item questionnaire that assessed peer relationships. Following Michelini and colleagues (2019), we will rescore two items assessing the number of close female and male friends using the following windows: 0 = 0; 1 = 1; ... 10 = 10; 11 to 100 = 11. Similarly, we will rescore two items on the number of other female and male friends with the following windows: 0 = 0; 1 = 1; ... 10 = 10; 11 to 15 = 11; 16 to 20 = 12; 21 to 25 = 13; 26 to 30 = 14; 31 to 100 = 15. The total of the 4 items will be coded as a count variable. Peer relationships were assessed T1-T4.

**Family conflict (Parent-Report).** Conflict within the family was assessed using 9 items from the Family Conﬂict subscale of the Moos Family Environment Scale (FES; “*example items*”). Parents rated each item as true or false, and these were assigned a value of 0 (false) or 1 (true), with higher scores indicating more family conflict. Family conflict was assessed T1-T4.

1. **How many and which conditions will participants be assigned to? (optional)**

This is a longitudinal observational study, and no random assignment is involved.

1. **Specify exactly which analyses you will conduct to examine the main question/hypothesis. (optional)**

**Aim 1: Identify the hierarchical structure of externalizing symptoms in the ABCD study.**

To examine the hierarchical structure of externalizing symptoms in ABCD study, we will use the 44 items/composites identified in Michelini et al. (2019) that loaded on the broad-based externalizing dimension. Specifically, we will use the psych package (Revelle, 2023) to implement both parallel analysis and the minimum average partial correlation (MAP) which will estimate the number of factors to extract from the 44 items/composites.

Next, we will use Forbes’ (2023) recently developed extension to Goldberg’s original (Goldberg, 2006) “bass-ackwards” analysis to identify the hierarchical structure of externalizing items/composites. Specifically, the ﻿ExtendedBassAckward function (Forbes, 2023) will be used to conduct a series of exploratory factor analyses with the maximum number of factors to be extracted determined by the results of parallel analysis/MAP mentioned above. Factors will be extracted using the minimum residual correlation method based on polychoric correlations and we will use an oblique factor rotation (promax). Though parallel analysis/MAP will be used to identify the maximum number of factors to extract, these methods can result in factor overextraction where some factors are not substantively meaningful. Thus, we will ensure that factors are interpretable and are not methodological artifacts (e.g., the result of forcing a particular number of factors to be extracted).

The ExtendedBassAckward approach is similar to the traditional bass-ackwards analysis, where a single factor is extracted at the first level of the hierarchy, and an additional factor is extracted at each subsequent level of the hierarchy. The ExtendedBassAckward differs from the traditional bass-ackwards approach in that it ﻿1) identifies redundant components that perpetuate through multiple levels of the hierarchy; 2) aids in identification of artefactual components; and 3) plots the strongest factor correlations among the remaining factors to identify their hierarchical structure. Although past work has used similar factor analytic approaches (e.g., Michelini et al., 2019), by constraining our analyses to only focus on the 44 CBCL items/composites associated with broad-based externalizing it is likely that differences will emerge in the hierarchical structure of the CBCL items/composites. The purpose of using such an approach is to have an empirically identified structure for externalizing dimensions before moving to more complex modeling approaches.

Our criteria for which CBCL externalizing items/composites will be used to model externalizing dimensions in subsequent analyses are as follows:

1. CBCL externalizing items/composites will be retained for the broad-externalizing dimension if they have a primary loading of .35 or higher. The broad-externalizing factor will be the first factor extracted using the extended bass-ackward analysis.
2. CBCL externalizing items/composites will be retained for the antagonistic and disinhibited dimensions if they have a primary loading of .35 or higher on either of the factors. In contrast to the broad-externalizing dimension, we do not have *a priori* hypotheses detailing which level of the hierarchy will reflect the antagonistic and disinhibited dimensions. However, if parallel analysis and MAP suggest a relatively large number of factors to be extracted (e.g., 5 or more), we expect that the antagonistic and disinhibited dimensions will emerge relatively early in the factor extraction process (e.g., at level 2 or level 3) given that they still reflect relatively broad dimensions of psychopathology. Substantively, we expect these factors to be comprised of CBCL items reflecting content consistent with past conceptualizations of antagonism (i.e., content related to callousness, combativeness, deceitfulness, grandiosity, and manipulativeness) and disinhibition (i.e., content related to nonplanfulness, irresponsibility, rashness, and risk-taking).

**Aim 2: Assess the longitudinal measurement invariance of externalizing, antagonism, and disinhibition spectra**

Following the extended bass-ackwards analyses, our analyses will focus on longitudinal change in latent externalizing factors. First, we will examine the longitudinal measurement invariance of each externalizing factor (identified using the criteria above) through a series of confirmatory factor analyses (CFA). Longitudinal measurement invariance will be examined by first using a CFA to test for configural measurement invariance and including constraints in a step-by-step fashion. We will first examine configural invariance, then weak invariance (by adding constraints to factor loadings), then strong invariance (by adding constraints for item intercepts), then strict invariance (by adding constraints on item residuals.

For tests of longitudinal measurement invariance, criteria for significant decrements in model fit will be based on the recommendations of Cheung and Rensvold (2002) which focus on CFI, gamma hat, and McDonalds non-centrality index (NCI). Specifically, a ∆CFI ≤ -.01 will be taken as evidence that the null hypothesis of invariance should not be rejected. ﻿For ∆Gamma hat and ∆McDonald’s NCI, the critical values will be -.001 and -.02, respectively. We will use the following indices to examine overall model fit at each time point: AIC, BIC, RMSEA, CFI, and TLI. Criteria for adequate model fit will be based on Schermelleh-Engel et al. (2003), which are as follows: RMSEA; acceptable fit: < .08, good fit: < .05); CFI and TLI; acceptable fit: .95-97, good fit: >.97. Thus, both relative and absolute model fit indices will be examined.

Importantly, using a large number of individual CBCL items will substantially increase the complexity of the longitudinal measurement invariance models and latent change score models. To mitigate this issue, we will create item parcels from the CBCL items that demonstrate adequate loadings (i.e., primary loading ≥.35). CBCL items will be randomly assigned to parcels and the lower limit of items included in any given parcel will be 6 items.

For example, if all 44 CBCL items/composites detailed in Table 1 demonstrated adequate primary loadings on the broad-based externalizing dimension, we will create 7 item parcels of randomly selected items; 6 parcels each comprised of 6 randomly selected items, and 1 parcel comprised of 8 randomly selected items. These item parcels would then serve as the observed indicators of the latent externalizing factor for our test of longitudinal measurement invariance. The item parcels that are initially created to test longitudinal measurement invariance will be retained for the latent change score models used for Aims 3 and 4.

Importantly, because our primary interests lie in the latent externalizing spectra/superspectrum, the use of item parcels is consistent with general recommendations regarding the use of items or parcels of items as indicators of latent constructs (e.g., when the focus is relations among latent variables, item-level information like cross-loadings and correlated residuals are less important; Little et al., 2013)

Representative MPlus code that will be used to examine longitudinal invariance of the externalizing dimension is below. Note that the MPlus code tests for strict invariance (rather than providing code for each step). The same code will be used for antagonistic and disinhibited dimensions, while creating item parcels from the specific CBCL items with loadings ≥.35 on the respective factors. Additionally, the code below assumes all 44 CBCL externalizing items/composites from Table 1 will be used to create item parcels for the analyses; we note that some items may not be used in our analyses depending on the results of the bass-ackwards analysis.

TITLE: Longitudinal Externalizing Factor Model-Strict Invariance;

DATA: FILE = ABCD.csv;

VARIABLE:

NAMES =

id

t1cbcl\_1-t1cbcl\_7 !Time 1 item parcels (assuming 7 parcels are created)

t2cbcl\_1-t2cbcl\_7 !Time 2 item parcels

t3cbcl\_1-t3cbcl\_7 !Time 3 item parcels

t4cbcl\_1-t4cbcl\_7; !Time 4 item parcels

MISSING = ALL (9999);

USEVAR =

t1cbcl\_1-t1cbcl\_7

t2cbcl\_1-t2cbcl\_7

t3cbcl\_1-t3cbcl\_7

t4cbcl\_1-t4cbcl\_7;

ANALYSIS:

ESTIMATOR=MLR;

MODEL:

!Latent Factors

ext\_1 BY t1cbcl\_1\* (lambda\_1) !constrain factor loadings to be equal over time; asterisk

t1cbcl\_2 (lambda\_2) !overrides default of fixing loading @ 1

t1cbcl\_3 (lambda\_3)

t1cbcl\_7 (lambda\_7);

ext\_2 BY t2cbcl\_1\* (lambda\_1)

t2cbcl\_2 (lambda\_2)

t2cbcl\_3 (lambda\_3)

t2cbcl\_7 (lambda\_7);

ext\_3 BY t3cbcl\_1\* (lambda\_1)

t3cbcl\_2 (lambda\_2)

t3cbcl\_3 (lambda\_3)

t3cbcl\_7 (lambda\_7);

ext\_4 BY t4cbcl\_1\* (lambda\_1)

t4cbcl\_2 (lambda\_2)

t4cbcl\_3 (lambda\_3)

t4cbcl\_7 (lambda\_7);

!Latent Variable Variances & Covariances

ext\_1@1 ext\_2 ext\_3 ext\_4; !fix ext\_1 variance at 1; estimate others

ext\_1 WITH ext\_2 ext\_3 ext\_4;

ext\_2 WITH ext\_3 ext\_4;

ext\_3 WITH ext\_4;

!Latent Variable Means

[ext\_1@0 ext\_2\*0 ext\_3\*0 ext\_4\*0]; !fix ext\_1 mean at 0; estimate others with 0 as starting value

!Unique Variances

t1cbcl\_1 t2cbcl\_1 t3cbcl\_1 t4cbcl\_1 (theta\_1); !constrain unique variances to be equal over time

t1cbcl\_2 t2cbcl\_2 t3cbcl\_2 t4cbcl\_2 (theta\_2);

t1cbcl\_7 t2cbcl\_7 t3cbcl\_7 t4cbcl\_7 (theta\_7);

!Observed Variable Intercepts

[t1cbcl\_1 t2cbcl\_1 t3cbcl\_1 t4cbcl\_1] (tau\_1); !constrain means to be equal over time

[t1cbcl\_2 t2cbcl\_2 t3cbcl\_2 t4cbcl\_2] (tau\_2);

[t1cbcl\_7 t2cbcl\_7 t3cbcl\_7 t4cbcl\_7] (tau\_7);

!Covariances for CBCL parcels’ unique variance

t1cbcl\_1 WITH t2cbcl\_1 t3cbcl\_1 t4cbcl\_1;

t2cbcl\_1 WITH t3cbcl\_1 t4cbcl\_1;

t3cbcl\_1 WITH t4cbcl\_1;

t1cbcl\_7 WITH t2cbcl\_7 t3cbcl\_7 t4cbcl\_7;

t2cbcl\_7 WITH t3cbcl\_7 t4cbcl\_7;

t3cbcl\_7 WITH t4cbcl\_7;

Establishing longitudinal measurement invariance is essential prior to examining longitudinal change in latent factors, and at minimum, strong invariance should be established to examine change at the latent factor level over time (Grimm et al., 2017). Thus, if strong longitudinal measurement invariance is not established, we will identify which CBCL externalizing item parcels demonstrate noninvariance over time. If noninvariant parcels make up 15% or less of the total indicators (e.g., out of 7 parcels, 1 is noninvariant), they will be removed from the measurement model and measurement invariance will be reexamined. This will allow for the latent externalizing dimensions to be estimated with identical sets of items across time.

If our initial strategy is not suitable (e.g., out of 7 parcels, 3 are invariant), we will take a two-step partial measurement invariance approach. First, invariant indicators will be identified using modification indices. Next, identified noninvariant indicators will be freed (i.e., allowed to be noninvariant) and the model re-estimated. If partial measurement invariance is established, we will move forward with our subsequent analyses.

**Aims 3: Examine baseline levels and within-individual change in latent spectra, and their respective associations with clinically relevant outcomes (e.g., psychopathology, psychosocial functioning).**

**Aim 4: Examine how risk and resilience factors (e.g., parenting style, neighborhood) impact baseline levels and within-individual change in latent spectra.**

We will model longitudinal change in latent externalizing dimensions using latent change score models. Latent change score models will allow us to test our hypotheses associated with Aims 3 and 4. Specifically, latent change score models allow for examining both proportional and constant change in latent dimensions. In addition, latent change score models can accommodate predictors of both latent intercept and growth parameters, as well as predictors of latent change scores.

For Aim 3, latent externalizing scores will be saved and then correlated with the following outcomes: symptom counts for parent-reported (T1-T4) and youth-reported (when available) conduct disorder, oppositional defiant disorder, substance use disorders, ADHD, major depressive disorder, suicidality/self-harm, generalized anxiety disorder, and social anxiety disorder, and youth-reported prosocial behavior (T1-T4), aggressive behavior (T3-T4), and impulsivity (T1 and T3). Though these associations can be included directly in the latent change score models as regression paths, it would substantially increase the number of parameters to be estimated (e.g., there are ≥ 11 regression coefficients to be estimated for each latent variable). Thus, to potentially avoid model convergence issues, we will used saved factor scores rather than directly estimate these associations within the latent change score models.

For Aim 4, our analyses will incorporate the following predictors: neighborhood safety, school connectedness, peer relationships, and family conflict. These predictors will be examined simultaneously in the models (i.e., we will account for their overlap when estimating their relations with outcomes).

All models will be examined separately for each latent externalizing dimension, for a total of three separate models for Aim 3 and Aim 4 (Model 1: modeling latent changes in broad externalizing, Model 2: modeling latent changes in antagonistic externalizing; Model 3: modeling latent changes in disinhibited externalizing).

Representative code for Model 1 (latent externalizing) for Aim 4 is below. In this model, latent externalizing is estimated using 7 item parcels comprised of all 44 CBCL items/composites. Predictors of latent intercepts, latent growth factors, and latent change scores are neighborhood safety, school connectedness, peer relationships, and family conflict.

﻿

TITLE: Latent Change Score Model - Externalizing;

DATA: FILE = ABCD.csv;

VARIABLE:

NAMES =

id

t1cbcl\_1-t1cbcl\_7 !CBCL parcels at baseline (t1)

t2cbcl\_1-t2cbcl\_7 !CBCL parcels at 1yr follow-up (t2)

t3cbcl\_1-t3cbcl\_7 !CBCL parcels at 2yr follow-up (t3)

t4cbcl\_1-t4cbcl\_7 !CBCL parcels at 3yr follow-up (t4)

peer fam\_conf neighbd school; !risk/resilience factors at baseline (t1)

MISSING = ALL (9999);

USEVAR =

t1cbcl\_1-t1cbcl\_7

t2cbcl\_1-t2cbcl\_7

t3cbcl\_1-t3cbcl\_7

t4cbcl\_1-t4cbcl\_7

peer fam\_conf neighbd school;

ANALYSIS:

ESTIMATOR=MLR;

MODEL = NOCOVARIANCES; !We will manually specify relations between latent variables

MODEL:

!Latent Externalizing Scores

ext1 BY t1cbcl\_1

t1cbcl\_2

t1cbcl\_3

t1cbcl\_7;

ext2 BY t2cbcl\_1

t2cbcl\_2

t2cbcl\_3

t2cbcl\_7;

ext3 BY t3cbcl\_1

t3cbcl\_2

t3cbcl\_3

t3cbcl\_7;

ext4 BY t4cbcl\_1

t4cbcl\_2

t4cbcl\_3

t4cbcl\_7;

[ext1-ext4@0]; !fix latent intercepts at 0

ext1-ext4@0; !fix latent intercepts at 0

[t1cbcl\_1-t1cbcl\_7@0]; !intercepts for observed scores fixed at 0

[t2cbcl\_1-t2cbcl\_7@0];

[t3cbcl\_1-t2cbcl\_7@0];

[t4cbcl\_1-t2cbcl\_7@0];

t1cbcl\_1 t2cbcl\_1 t3cbcl\_1 t4cbcl\_1 (sigma2\_1); !constrain variances to be equal over time

t1cbcl\_2 t2cbcl\_2 t3cbcl\_2 t4cbcl\_2 (sigma2\_2);

t1cbcl\_7 t2cbcl\_7 t3cbcl\_7 t4cbcl\_7 (sigma2\_7);

!Autoregressions

ext2 ON ext1@1;

ext3 ON ext2@1;

ext4 ON ext3@1;

!Latent Change Scores

dext2 BY ext2@1;

dext3 BY ext3@1;

dext4 BY ext4@1;

[dext2-dext4@0];

dext2-dext4@0;

!Constant Change Component

gext BY dext2-dext4@1; !growth factor

gext;

[gext];

﻿iext by ext1@1; !baseline intercept

iext;

[iext];

iext WITH gext; !covariance between growth factor and intercept

!Proportional Effects

dext2 ON ext1 (pi); !constrain our proportional effects to be equal over time to aid estimation

dext3 ON ext2 (pi);

dext4 ON ext3 (pi);

!Exogenous Predictors (predicting latent intercept/growth factors and latent change scores)

iext gext on peer fam\_conf neighbd school;

dext2 on peer fam\_conf neighbd school;

dext3 on peer fam\_conf neighbd school;

dext4 on peer fam\_conf neighbd school;

﻿SAVEDATA: !Save factor scores for analyses focused on clinical/psychosocial outcomes

file is EXTfscores.txt;

save = fscores;

1. **Any secondary analyses? (optional)**

We have no secondary analyses currently planned.

1. **How many observations will be collected or what will determine the sample size? No need to justify decision but be precise about exactly how the number will be determined. (optional)**

This is a secondary data analysis using the ABCD dataset so no *a priori* power analysis was conducted to determine sample size for our specific analyses. However, simulation-based power analyses focused on a latent change score model suggest that we will have high power (>.90) to detect even small (β=.10) effects of interest (i.e., proportional change in latent externalizing dimensions).

Though these initial power analyses are informative, latent change score models involve a large number of parameters, some of which are difficult to estimate *a* *priori*, but nonetheless can have important implications for power (e.g., the covariance between the latent growth and intercept factors). Thus, we plan to conduct additional sensitivity analyses for our primary effects of interest (proportional change in latent externalizing dimensions) after estimating latent change score models. Values for model parameters will be derived from the sample results and used as input values for sensitivity analyses. These analyses will provide more informed estimates of power for the effects of interest. Sensitivity analyses will be conducted in MPlus using Monte Carlo simulation methods.

1. **Anything else you would like to pre-register? (e.g., data exclusions, variables collected for exploratory purposes, unusual analyses planned?) (optional)**

*CBCL Item Exclusions and Composites*

In their initial exploratory factor analyses using the 119 CBCL items, Michelini et al. (2019) identified a series of CBCL items with very low endorsement (<0.5% rated as 1 or 2) and also identified items that were very highly correlated (polychoric *r* >.75). Based on low endorsement rates, they removed the following items: “Drinks alcohol without parents' approval”, “Sexual problems”, “Smokes, chews, or sniffs tobacco”, “Truancy, skips school”, “Uses drugs for non-medical purposes (don't include alcohol or tobacco)”.

Additionally, the authors created 9 composite variables based on high correlations among some items, and the following 6 composites loaded on the externalizing factor: Attacks/threatens (“Physically attacks people”, “Threatens people”); Destroys (“Destroys his/her own things”, “Destroys things belonging to his/her family or others”, “Vandalism”); Disobeys rules (“Disobedient at home”, “Disobedient at school”, “Breaks rules at home, school or elsewhere”); Steals (“Steals at home”, “Steals outside the home”); Peer problems (“Doesn't get along with other kids”, “Not liked by other kids”); Distracted/Hyperactive (“Can't concentrate, can't pay attention for long”, “Inattentive or easily distracted”, “Can't sit still, restless, or hyperactive”).

For our analyses, we will exclude the same items across all timepoints and will use the same composites across all time points.

*Missing Data*

Although the ABCD study has low attrition rates across assessment periods and thus missing data is likely to be limited, we will use full-information maximum likelihood (FIML; the default approach in MPlus) to handle missing data for our analyses of longitudinal measurement invariance and latent change scores.

*Alternative Factoring Method for Bass-ackwards Analyses*

The ExtendedBassAckward function will be used in our first set of analyses focuses on the structure of CBCL externalizing items/composites. However, the ExtendedBassAckward function only supports either principal components analysis or minimum residual factoring in the case of exploratory factor analysis. Because there is debate regarding the most appropriate factoring method to use for ordinal data (i.e., CBCL items), we will also examine whether results regarding the hierarchical structure of externalizing differ when weighted least squares is used as the factoring method (while using an oblique equamax rotation). This method will be implemented using the psych package and its bassackward function. The oblique equamax rotation will be applied using the GPArotation package (Bernaards & Jennrich, 2005).

*Alpha adjustment*

Due to the large number of correlational significance tests involving the latent externalizing dimension factor scores and clinical outcomes, we will use a more stringent alpha value of .01 for these tests.

References

Bernaards, C. A., & Jennrich, R. I. (2005). Gradient projection algorithms and software for arbitrary rotation criteria in factor analysis. *Educational and Psychological Measurement, 65*(5), 770–790. <https://doi.org/10.1177/0013164404272507>

Bongers, I. L., Koot, H. M., van der Ende, J., & Verhulst, F. C. (2004). Developmental trajectories of externalizing behaviors in childhood and adolescence. *Child Development*, *75*(5), 1523–1537. https://doi.org/10.1111/j.1467-8624.2004.00755.x

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating Goodness-of-Fit Indexes for Testing Measurement Invariance. *Structural Equation Modeling*, *9*(2), 233–255.

Clark, D. A., Hicks, B. M., Angstadt, M., Rutherford, S., Taxali, A., Hyde, L., Weigard, A., Heitzeg, M. M., & Sripada, C. (2023). The General Factor of Psychopathology in the Adolescent Brain Cognitive Development (ABCD) Study: A Comparison of Alternative Modeling Approaches. *Clinical Psychological Science*, 1–23.

Forbes, M. K. (2023). Improving hierarchical models of individual differences: An extension of Goldberg’s bass-ackward method. *Psychological Methods*, 1–20. https://doi.org/10.1037/met0000546

Goldberg, L. R. (2006). Doing it all Bass-Ackwards: The development of hierarchical factor structures from the top down. *Journal of Research in Personality*, *40*(4), 347–358. https://doi.org/10.1016/j.jrp.2006.01.001

Grimm, K. J., Ram, N., & Estabrook, R. (2017). *Growth Modeling: Structural Equation Modeling and Multilevel Modeling Approaches*. Guilford Press. www.guilford.com/MSS

Little, T. D., Rhemtulla, M., Gibson, K., & Schoemann, A. M. (2013). Why the items versus parcels controversy needn’t be one. *Psychological Methods*, *18*(3), 285–300. https://doi.org/10.1037/a0033266

Michelini, G., Barch, D. M., Tian, Y., Watson, D., Klein, D. N., & Kotov, R. (2019). Delineating and validating higher-order dimensions of psychopathology in the Adolescent Brain Cognitive Development (ABCD) study. *Translational Psychiatry*, *9*(1), 21–25. https://doi.org/10.1038/s41398-019-0593-4

Miner, J. L., & Clarke-Stewart, K. A. (2008). Trajectories of Externalizing Behavior from Age 2 to Age 9: Relations With Gender, Temperament, Ethnicity, Parenting, and Rater. *Developmental Psychology*, *44*(3), 771–786. https://doi.org/10.1037/0012-1649.44.3.771

Moore, T. M., Kaczkurkin, A. N., Durham, E. L., Jeong, H. J., McDowell, M. G., Dupont, R. M., Applegate, B., Tackett, J. L., Cardenas-Iniguez, C., Kardan, O., Akcelik, G. N., Stier, A. J., Rosenberg, M. D., Hedeker, D., Berman, M. G., & Lahey, B. B. (2020). Criterion validity and relationships between alternative hierarchical dimensional models of general and specific psychopathology. *Journal of Abnormal Psychology*, *129*(7), 677–688. https://doi.org/10.1037/abn0000601

Revelle, W. (2023). psych: Procedures for Psychological, Psychometric, and Personality Research. Northwestern University, Evanston, Illinois. R package version 2.3.3, [https://CRAN.R-project.org/package=psych](https://cran.r-project.org/package=psych).

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *MPR-Online*, *8*(2), 23–74.